EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Dominik Hirschbühl, Georgi Krustev,
Grigor Stoevsky

Financial drivers of the euro area business cycle: a DSGE-based approach

No 2475 / October 2020

Abstract

We estimate a modified version of the "Financial Business Cycles" model originally developed by Iacoviello (2015) in order to investigate the role played by financial factors in driving the business cycle in the euro area. In the model, financial shocks such as borrower defaults, collateral shocks and credit supply effects amplify economic downturns by reducing the flow of credit from banks to the real sector. In this novel application to the euro area, we introduce capital reallocation inefficiency, an innovation to the original set-up which allows for more realistic effects of entrepreneur defaults on economic activity. Our results suggest that financial factors, as captured by this model, played a smaller role in the euro area throughout the double-dip recession than in the United States during the 2008-09 global financial crisis. In a scenario on second-round effects implied by potential NFC loan losses due to the COVID-19 pandemic, we find large financial amplification risks to real economic activity.

JEL Classification: E32; E44; E47.

Keywords: DSGE; Bayesian estimation; housing; financial frictions.

Non-technical summary

A decade on, the US financial sector has recovered from the global financial crisis while the euro area still suffers from high levels of non-performing loans (NPLs), which act as a drag on credit growth and economic activity. With swings in the financial cycle arguably becoming larger in recent decades, the financial sector has gained momentum as a driver of real economic activity at the expense of other structural factors.

We employ a modified version of the "Financial Business Cycles" model described by Iacoviello (2015) to disentangle the underlying financial and real drivers of the business cycles in the United States and the euro area. This is a real business cycle (RBC) model augmented with a banking sector and featuring financial frictions on households, firms and banks. Through the lens of this model, financial shocks involving the interplay of borrower defaults, changes in asset prices and credit supply conditions act alongside traditional drivers such as preference and technology shocks. The model has at its core default shocks on private loans, which redistribute wealth away from banks and are then transmitted to the real sector via a credit crunch. Additional financial mechanisms in the model include asset price fluctuations stemming from housing preference shocks and changes in credit supply conditions in the form of loan-to-value (LTV) shocks.

Iacoviello (2015) finds that financial shocks account for about two–thirds of the observed collapse in output in the US during the Great Recession. We make four new contributions to the topic. First, we modify the original model by introducing entrepreneur capital reallocation inefficiency. In line with the findings of Ramey and Shapiro (2001), we augment the depreciation function, so that an entrepreneur default shock leads to a proportionate rise in the depreciation rate of entrepreneur capital. This offsets the positive income effect in the model, resulting from the redistribution of resources from the banker towards the entrepreneur. The modified version of the model produces a more realistic characterisation of the economic effects of this shock. Second, we use Bayesian methods to estimate the modified version of the model for the euro area and analyse the contribution of financial factors to business cycle fluctuations since the global financial crisis. Third, we extend the US dataset to cover the period up to 2018, use it to re-estimate the modified version of the model for the United States and then present a comparative analysis of the crisis and post-crisis dynamics across the two economies. Fourth, we run scenarios to quantify the financial amplification second-round effects implied by potential increases in NFC loan losses.

Our findings are as follows.

(i) Incorporating capital reallocation inefficiency in the model produces a more realistic response in economic activity to entrepreneur defaults.

(ii) The estimation results for the euro area indicate that financial factors played a relatively small role in driving the downturn in its business cycle around the global financial crisis, with only one-fifth to one-quarter of the double-dip recession being attributable to adverse financial shocks. By contrast, financial factors have played a stronger role in the subsequent recovery contributing to more than two-fifths of euro area output growth between 2014 and 2018.

(iii) Re-estimating the modified version of the model using the extended dataset for the United States broadly confirms the original conclusions of Iacoviello (2015), who finds that financial shocks accounted for about two–thirds of the observed collapse in output in the United States during the Great Recession. While close to this original estimate, our updated results point to a slightly weaker contribution of financial factors to the decline in US GDP in 2008-09. As in the euro area, financial shocks played a substantial role in the subsequent recovery in the United States. Based on these results, we conclude that financial factors played a smaller role throughout the double-dip recession in the euro area than during the global financial crisis in the US.

(iv) In light of the more recent and unprecedented economic slump due to the coronavirus (COVID-19) pandemic, we find potentially large financial amplification effects for the euro area in scenarios with strong increases in bank losses on loans to non-financial corporations. More specifically, we find that scenarios with cumulative bank losses in the range of 3% to 11.5% of NFC loans result in second-round effects with declines in output in the euro area ranging from 0.5% to 1.7% at its trough, five quarters after the shock.

1 Introduction

A decade on, the US financial sector has recovered from the global financial crisis while the euro area still suffers from high levels of non-performing loans (NPLs) which act as a drag on credit growth and economic activity. With swings in the financial cycle arguably becoming larger in recent decades, the financial sector has gained momentum as a driver of real economic activity at the expense of other structural factors.

We employ a modified version of the "Financial Business Cycles" model described by Iacoviello (2015) to disentangle the underlying financial and real drivers of the business cycles in the United States and the euro area. This is a real business cycle (RBC) model augmented with a banking sector and featuring financial frictions on households, firms and banks. Through the lens of this model, financial shocks involving the interplay of borrower defaults, changes in asset prices and credit supply conditions act alongside traditional drivers such as preference and technology shocks. The model has at its core default shocks on private loans, which redistribute wealth away from banks and are then transmitted to the real sector via a credit crunch. Additional financial mechanisms in the model include asset price fluctuations stemming from housing preference shocks and changes in credit supply conditions in the form of loan-to-value (LTV) shocks. The model is estimated with Bayesian techniques as described by An and Schorfheide (2007).

The global financial crisis has brought about renewed interest in the interactions between the real and financial sides of the economy. The importance of financial factors as drivers of modern business cycles has been well documented in the literature since the financial crisis (see Jordá et al., 2013). For example, Bernanke (2018) concludes that credit factors deserve closer attention from macroeconomists not only for analysing the economic effects of the crisis but also for understanding business cycles in regular times. He provides new evidence that the deterioration of household balance sheets and the associated deleveraging were responsible for the initial economic downturn and the sluggish recovery, and that the severity of the recession was driven by disruptions in the supply of credit, initiated by panic in financial markets. Furlanetto et al. (2019) use a vector autoregression (VAR) with sign restrictions to evaluate the importance of financial factors (housing, credit and uncertainty) for US business cycle fluctuations. They find that housing shocks played a dominant role during the Great Recession and that LTV shocks (which can be interpreted as credit supply shocks) have more substantial effects than uncertainty shocks, which are found to be short-lived. Justiniano et al. (2019) show that an increase in credit supply caused by looser lending conditions in the mortgage market was the key driver in housing market dynamics before the Great Recession, explaining the unprecedented rise in house prices, the surge in household debt, the stability of debt relative to home values and the fall in mortgage rates. In a two-country model featuring a global bank, Kollmann et al. (2011) find that the impact of loan default shocks is negligible under normal economic conditions, while substantial loan losses originating in one country result in a sizeable and simultaneous decline in economic activity in both economies. The authors conclude that global banks might have played a significant role in the global financial crisis as large credit losses in the US mortgage market resulted in sharp output reduction in the United States and the euro area. In an estimated DSGE model for the euro area, Gerali et al. (2010) explore the link between loan availability and the business cycle, which derives from balance-sheet constraints within the banking sector. They find that the destruction of bank equity, which could stem from unexpected defaults, has substantial repercussions for the economy. Similarly, Guerrieri et al. (2019) discuss the macroeconomic spillover effects of capital shortfalls in the financial intermediation sector across various models. They show that although different models emphasise different transmission channels, the predicted outcomes are broadly similar.

Iacoviello (2015) finds that financial shocks accounted for about two–thirds of the observed collapse in output in the United States during the Great Recession. Building on his "Financial Business Cycles" model, we make four new contributions to the debate. First, we modify the original model by introducing entrepreneur capital reallocation inefficiency. In line with the findings of Ramey and Shapiro (2001), we augment the depreciation function, so that an entrepreneur default shock leads to a proportionate rise in the depreciation rate of entrepreneur capital. This offsets the positive income effect in the model, resulting from the redistribution of resources from the banker towards the entrepreneur. The change to the model set-up produces a more realistic characterisation of the economic effects of this shock. Second, using Bayesian methods, we estimate the new version of the model on euro area data and analyse the contribution of financial factors to euro area business cycle fluctuations. Third, we extend the US dataset to cover the period up to 2018, use it to re-estimate the modified version of the model for the United States and then present a comparative analysis of the crisis and post-crisis dynamics across the two economies. Fourth, we run scenarios to quantify the second-round financial amplification effects stemming from potential increases in non-financial corporation (NFC) loan losses due to the COVID-19 pandemic.

Our findings are as follows.

(i) Incorporating capital reallocation inefficiency in the model produces a more realistic response in economic activity to entrepreneur defaults.

(ii) The estimation results for the euro area indicate that financial factors played a relatively small role in driving the downturn in its business cycle around the global financial crisis, with only one-fifth to one-quarter of the double-dip recession being attributable to adverse financial shocks. By contrast, financial factors have played a stronger role in the subsequent recovery contributing to more than two-fifths of euro area output growth between 2014 and 2018.

(iii) Re-estimating the modified version of the model using the extended dataset for the United States broadly confirms the original conclusions of Iacoviello (2015), who finds that financial shocks accounted for about two–thirds of the observed collapse in output in the United States during the Great Recession. While close to this original estimate, our updated results point to a slightly weaker contribution of financial factors to the decline in US GDP in 2008-09. As in the euro area, financial shocks played a substantial role in the subsequent recovery in the United States. Based on these results, we conclude that financial factors played a smaller role throughout the double-dip recession in the euro area than during the global financial crisis in the US.

(iv) In light of the more recent and unprecedented economic slump due to the coronavirus (COVID-19) pandemic, we find potentially large financial amplification effects for the euro area in scenarios with strong increases in bank losses on loans to non-financial corporations. More specifically, we find that scenarios with cumulative bank losses in the range of 3% to 11.5% of NFC loans result in second-round effects with declines in output in the euro area ranging from 0.5% to 1.7% at its trough, five quarters after the shock.

The paper is structured as follows. Section 2 illustrates the model's features, key transmission channels and the augmentation which was made to account for capital reallocation inefficiency. Section 3 discusses the data used in the estimations for the United States and the euro area and the necessary adjustments that have been implemented. Section 4 discusses the empirical results, covering calibration and estimation, impulse response analysis and historical decomposition, as well as existing caveats. Section 5 presents the sensitivity analysis, while Section 6 explores potential financial amplification effects from the COVID-19 pandemic. Finally, Section 7 offers some concluding remarks.

2 The model

In this section, we briefly describe the economy and the main transmission channels in the model. We provide key model equations in Appendix A; for a more detailed description, the reader is referred to Iacoviello (2015). The framework is an RBC model augmented with a banking sector and financial frictions on banks, households and entrepreneurs.

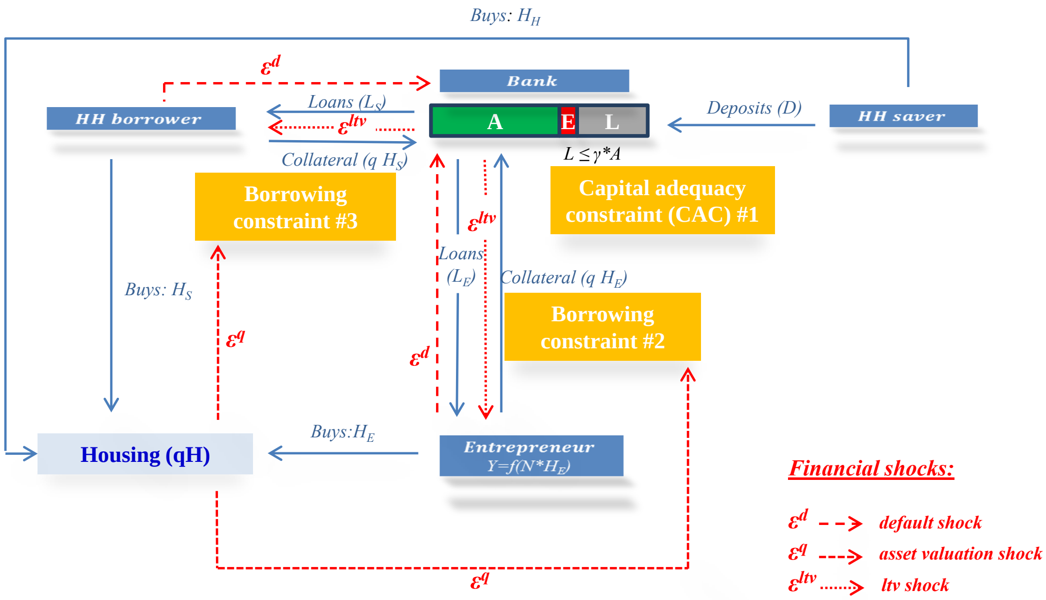
2.1 Main features of the model

There are four types of agents in the economy: patient households, impatient households, entrepreneurs and bankers. Both types of households work, consume and buy housing. In addition, patient households save, in the form of one-period deposits, and accumulate part of the capital stock in the economy. By contrast, impatient households borrow funds from banks, using their housing as collateral, and are subject to a borrowing constraint which depends – among other things – on the value of their housing, and thus on house price developments. Similarly, entrepreneurs take out loans from banks and secure them with housing (commercial real estate) as collateral. Transforming the loans into capital, they mix it with labour to produce final goods. Banks transform savings into loans. They face a borrowing constraint when obtaining deposits, as they are required to hold equity: capital adequacy requirements posit that bank equity must exceed, after expected losses, a proportion of bank assets. Appendix A contains further details on the model set-up, including the agents' objective functions and constraints.

The model distinguishes between financial and non-financial shocks, and incorporates quadratic adjustment costs (related to deposits, loans and capital) to account for the observed slow dynamics of the macroeconomic variables. It also features consumption habits and inertia in the borrowing and capital adequacy constraints. There are three financial frictions: bankers are constrained by how much they can borrow from patient households, while entrepreneurs and impatient households are each constrained by how much they can borrow from bankers.

2.2 The model's shocks and propagation mechanisms

Alongside traditional shocks (such as preference and technology shocks), the economy is subject to three types of financial shocks that affect the ability to borrow: repayment (default) shocks on loans, asset valuation shocks and changes in LTV ratios. These shocks are transmitted through the channels shown in a stylised way in Figure 1.



A repayment shock – also called a redistribution (or default) shock – transfers resources away from the bank's balance sheet to benefit the balance sheet of the defaulting agent (either the household borrower or the entrepreneur) as it decreases the agent's liabilities. While such default shocks relax the budget constraint of the borrower, they worsen the bank's budget constraint and capital adequacy constraint, triggering a credit crunch as the bank strives to improve its equity and restore its balance sheet to health. In practice, the shock to the bank's equity triggers the need to contract its assets by a multiple of its capital in order to restore the leverage ratio. The resulting reduction in credit availability induces recessionary effects. Similarly, a negative shock to housing preferences leads to a reduction in the value of collateral and borrowing capacity by lowering house prices, which results in lower loan volumes and lower consumption, investment and output. Lastly, LTV shocks – reflecting tighter credit supply conditions imposed by the banks – likewise have a recessionary impact by making the borrowing constraint tighter for impatient households and entrepreneurs.

2.3 Augmenting the model for capital reallocation inefficiency

In line with the findings of Ramey and Shapiro (2001), we modify the model by assuming that defaults on loans to entrepreneurs lead to a rise in the depreciation rate of entrepreneur capital. This produces a negative GDP reaction in response to entrepreneur defaults by neutralising the income effect arising from redistribution from banks to entrepreneurs. Otherwise, the entrepreneurs' problem remains the same as in Iacoviello (2015). Entrepreneurs obtain loans $L_{E,t}$ and produce goods Y_t by employing labour N_t from both patient and impatient households (denoted by subscripts H and S, respectively) and using housing $H_{E,t}$ and capital either produced by themselves, $K_{E,t}$, or rented from patient households, $K_{H,t}$. Similarly to bankers, they maximise their utility through consumption $C_{E,t}$

$$\max\ \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E^t (1-\eta) log\left(C_{E,t} - \eta C_{E,t-1}\right), \tag{1}$$

subject to the entrepreneur budget constraint

$$\begin{aligned} C_{E,t} + \frac{K_{E,t}}{A_{K,t}} + q_t H_{E,t} + R_{E,t} L_{E,t-1} + W_{H,t} N_{H,t} + W_{S,t} N_{S,t} + R_{M,t} z_{KH,t} K_{H,t-1} \\ = Y_t + \frac{1-\delta_{KE,t}}{A_{K,t}} K_{E,t-1} + q_t H_{E,t-1} + L_{E,t} - ac_{KE,t} - ac_{EE,t} + \epsilon_{E,t}, \end{aligned} \tag{2}$$

where $ac_{KE,t}$ and $ac_{EE,t}$ represent adjustment costs for capital and loans, the corresponding gross returns are denoted by $R_{M,t}$ and $R_{E,t}$ respectively, q_t is the price of housing in units of consumption, and W_t is the wage rate. As in the original model, entrepreneurs – in a similar way to households – are subject to an investment shock $A_{K,t}$ to which they can adjust their utilisation rate z_t, and pay a quadratic capital adjustment cost. The production function is given by

$$Y_t = A_{Z,t}(z_{KH,t}K_{H,t-1})^{\alpha(1-\mu)}(z_{KE,t}K_{E,t-1})^{\alpha\mu} H_{E,t-1}^{\nu} N_{H,t}^{(1-\alpha-\nu)(1-\sigma)} N_{S,t}^{(1-\alpha-\nu)\sigma}, \tag{3}$$

where $A_{Z,t}$ is a technological shock.

Given the budget constraint, there is a positive income effect from redistribution in the event of entrepreneur loan default shocks $\epsilon_{E,t}$, resulting in a positive output response. In the original model, which was designed to fit features of the US economy, this is of less importance, as household defaults initiated most losses in the economy during the global financial crisis. For the euro area, however, this would imply the real economy suffered no negative consequences from entrepreneur defaults during the crisis – an unrealistic result in view of the greater importance of corporate defaults in Europe. To rectify this implausible result, we modify the depreciation rate $\delta_{KE,t}$ to reflect the idea that the sectoral specificity of capital leads to misallocations in the case of default, as outlined by Ramey and Shapiro (2001). This modification results in an immediate depreciation of a portion, δ_ϵ, of its defaulted loans relative to its steady-state capital in the event of a company defaulting on its loans:

$$\delta_{KE,t} = \delta_{KE} + b_{KE}(0.5\zeta'_E z^2_{KE,t} + (1-\zeta')z_{KE,t} + (0.5\zeta'_e - 1)) + \delta_\epsilon \frac{\epsilon_{E,t}}{K^{ss}}, \qquad (4)$$

where $b_{KE} = \frac{1}{\beta_E} + (1-\delta_{KE})$ implies a unitary steady state utilisation rate.

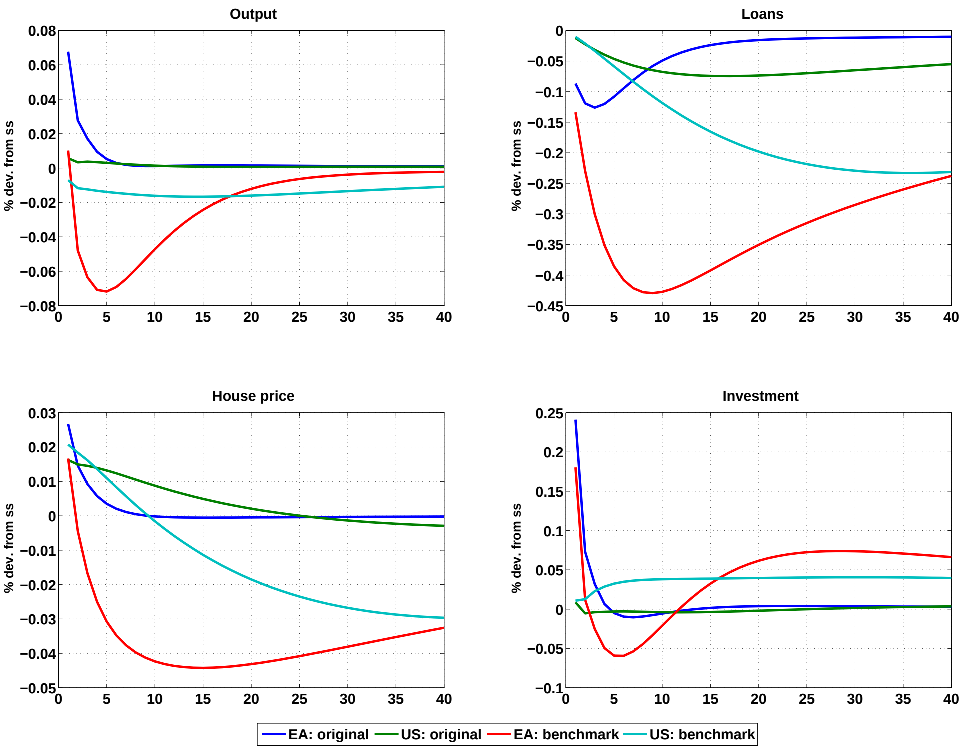
We set δ_ϵ to 0.65, meaning that 65% of the installed capital associated with the entrepreneur's loan depreciates after a default. This calibration approximates empirically the values observed in Ramey and Shapiro (2001) for aerospace capital goods sold outside the aerospace industry. Given the period of low growth after the double-dip recession and the limited alternatives for re-employing the capital goods, a large misallocation of capital in the case of defaults appears plausible.[1]

Figure 2 shows the estimated impulse responses to an entrepreneur default shock for the original model and the modified (benchmark) model for the euro area and the United States.

In the original model specification applied to the euro area, entrepreneur defaults imply an increase in investment and real GDP, while this counter-intuitive result turns out to be less pronounced for the US. Introducing capital reallocation inefficiency offsets the positive income effect which occurs in response to redistribution in the budget constraint, and leads to a persistent decrease in output and negative effects on investment. At the same time, the one-time default leading to initially higher depreciation implies a higher rate of capital utilisation, which feeds back endogenously into higher depreciation of capital.

[1] Choosing a different value for the parameter within a plausible range does not alter the negative effect on GDP resulting from entrepreneur defaults.

Figure 2 Impulse response to an *entrepreneur default shock*



Notes: Impulse responses to a 1 standard deviation *entrepreneur default shock*. Euro area *original* and United States *original* show the impulse responses for the unaugmented model. Euro area *benchmark* and the United States *benchmark* show the impulse responses for the model augmented with capital reallocation inefficiency. All responses are expressed in terms of percentage deviations from steady state.

3 Data used in the estimation

In this section, we discuss the data used in the estimations for the United States and the euro area, together with the adjustments that needed to be implemented. More details on the data sources for the euro area are provided in Appendix B.

The original model is estimated using US quarterly data for the period 1990-2010.[2] The model features eight structural shocks and eight corresponding observable variables: real consumption, real private non-residential fixed investment (both from US national accounts data), losses on loans to businesses, losses on loans to households (both approximated using loan charge-off data from the Federal Reserve Board), loans to businesses, loans to households (from the Financial Accounts of the United States), real house prices (based on the Federal Housing Finance Agency's House Prices Index), and total factor productivity (TFP). The GDP deflator is used to convert nominal series to real terms. Importantly, for TFP Iacoviello (2015) uses

[2] Using quarterly data for 1985-1989 as a training sample for the Kalman filter. For further details on the construction of the series for the United States see Appendix C in Iacoviello (2015).

external estimates adjusted for capacity utilisation, as constructed by Fernald (2014) – a series not yet available at quarterly frequency for the euro area.

The series are filtered before being used in the estimation. More specifically, consumption, investment, house prices, TFP and loans to both entrepreneurs and households are log-transformed and de-trended with a quadratic trend. Charge-off flows are scaled by steady-state GDP (where the steady-state is approximated by a cubic trend in the sum of nominal consumption and investment). Charge-off rates, originally obtained from the commercial banking sector, are applied to the total volume of loans received by non-financial businesses and households (reported in the flow-of-funds accounts) to ensure a coverage of total losses. GDP is the sum of private consumption and private non-residential investment.

3.1 Extended dataset for the United States and data for the euro area

The construction of the extended US dataset closely follows the sources and methods used by Iacoviello (2015). Extending the end date for the US dataset to 2018 results in slightly different estimates for the quadratic trends and cyclical fluctuations in the period around the global financial crisis. Nevertheless, the changes in trends have only minor consequences, leaving the results broadly unaffected.

The methods used by Iacoviello (2015) have also been employed to create the data for the euro area. In particular, it should be noted that real consumption and real investment are based on national accounts data, loans to households and to non-financial corporations are based on the respective liabilities in the Quarterly Sector Accounts (QSA), losses on loans are constructed by applying bank charge-off rates (calculated from the Balance Sheet Items (BSI) dataset in the ECB's Statistical Data Warehouse (SDW)) to loans reported in the sectoral liabilities section of the QSA, house prices are based on the Residential Property Price (RPP) data in the SDW, and TFP is calculated as a Solow residual from a Cobb-Douglas production function, using data available in the SDW and AMECO for the inputs.[3]

In preparing the latter dataset, some euro area-specific challenges need to be tackled. (i) As there is no official series for business (i.e. private non-residential fixed) investment, we use a proxy by subtracting general government and housing investment from total gross fixed capital formation. (ii) Owing to the lack of data, bank charge-offs are approximated by "Other adjustments in MFI loans", which represent a proxy for net write-offs, i.e. write-offs less write-off reversals (recoveries). (iii)

[3] AMECO is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs.

The TFP series has been calculated as a residual from a Cobb-Douglas production function, using the long-term average labour income share. This TFP series is not adjusted for factor utilisation.[4] We address the lack of adjustment in the data by augmenting the measurement equation for variable capital utilisation. We conduct a sensitivity exercise by applying the model to the US data, for which both series are available. Appendix D.2 documents the findings of this exercise, which supports the validity of our approach.

Following the construction of the raw series, the same pre-filtering is applied as in the original paper. The euro area quarterly dataset covers the period 2000-18, with the first five years being used to initialise the Kalman filter. A Bayesian estimation of the structural parameters and shock processes is applied on the 2005-18 sample.

3.2 Comparison of the euro area and the US datasets

Figure B.1 in Appendix B shows the eight data series used in the estimation of the model. Comparing developments in the euro area and the United States, a few observations need to be made. Consumption and business investment have broadly similar cyclical patterns in the two economies over the period considered. Losses on loans to entrepreneurs peak in the United States in the aftermath of the global financial crisis before declining, whereas they increase much more gradually in the euro area (apart from the peak in 2012 Q4, which reflects the transfer of NPLs to the Spanish "bad bank" Sareb[5]), and remaining relatively elevated until at least 2018. While reaching a peak in the United States in 2009 and subsequently dropping, losses on loans to households hardly increase at all in the euro area. House prices and loans to households and entrepreneurs exhibit much smaller cyclical amplitude in the euro area compared with the United States. The TFP series has a markedly different cyclical pattern in 2008-09 in the two economies: it increases in the United States (given the adjustment for factor utilisation), whereas it strongly drops and then recovers in the euro area.

Overall, differences in economic developments in the two economies, as captured by the different cyclical patterns of the key observable variables, largely determine the estimation results (in terms of parameters and shock processes) and hence the model interpretation of the structural drivers of the cyclical fluctuations in the euro area and in the United States.

[4] We are not aware of the existence of a utilisation-adjusted series for the euro area.

[5] For further details see European Central Bank (2013), Financial Stability Review, May, p. 63.

4 Results from the benchmark model

As outlined in Section 2, our benchmark model is adapted from the model originally developed by Iacoviello (2015) with a modification to account for capital reallocation inefficiency. In our benchmark model, entrepreneur defaults are associated with less efficient use of the reallocated capital, which is captured by a higher initial depreciation of capital proportionate to the default.

In this section, we present the estimation results for the benchmark model for the euro area and the United States, and analyse the contributions of financial factors to their respective business cycle fluctuations since the global financial crisis from a comparative perspective. The key findings are as follows:

- financial factors played a weaker role in the euro area during the double-dip recession than in the United States during the the global financial crisis;
- re-estimating the modified version of the model using the extended dataset for the United States broadly confirms the conclusions of Iacoviello (2015) regarding the importance of financial factors in driving the drop in US output during the Great Recession;
- in both the euro area and the United States, financial factors have played a substantial role in supporting GDP growth in the post-recession recovery.

4.1 Parameters and steady-state ratios in the model

Table C.1 in Appendix C sets out the *calibrated parameters* used when applying the benchmark model to the US and euro area data. We leave the parameterisation for both economies unchanged from the original model of Iacoviello (2015) in order to make it easier to compare the results across applications. Given that calibrated parameters are the same, differences between the model steady-state ratios between the EA and the US application are entirely driven by the estimated parameters, and hence reflect features in the data. It is worth noting that the interest rate structure is mainly influenced by the discount factors (betas), which are calibrated in such a way that the borrowing constraints bind in a neighbourhood of the steady state. The values for the discount factors used in the original model imply an annualised steady-state deposit rate of 3% and a steady-state lending rate of 5%. In using the same calibration, we implicitly assume that the US and euro area economies have similar interest rate structures in their respective steady states. With the chosen preference parameter for housing in the utility function ($j = 0.075$) and similar estimates for the housing share of entrepreneurs in the euro area and the United States, the steady-state housing stock-to-GDP ratio for both economies is around

160%. The LTV ratios for entrepreneurs (m_H and m_K) and household borrowers (m_S) and the leverage parameters for the bank (γ_E and γ_S) are set at 0.9 (implying that banks have a capital-to-assets ratio of 0.1). The calibration of the capital share in production (α) at 0.35 and the capital depreciation rates (δ_{KE} and δ_{KH}) at 0.035 implies a capital-to-output ratio of around 1.8.

Turning to the estimation results, Tables C.2 and C.4 in Appendix C display the *estimated structural parameters*, along with the assumed priors. As in Iacoviello (2015), the priors were chosen to ensure that the domain of most parameters covers a relatively wide range of outcomes. Comparing the estimation results for the euro area and the United States, we find the posterior mean habit persistence to be lower than the prior mean in both areas: it is estimated to be 0.47 for the United States and is found slightly lower for the euro area, at 0.44. The capital and housing shares of entrepreneurs (μ and ν) and the wage share of household borrowers (σ) are key parameters influencing the steady-state ratios of the model. Looking at the former set of parameters, while both estimates are lower than their respective prior means, the estimated capital share of entrepreneurs in the United States is lower than in the euro area, and the housing share of entrepreneurs in the production function is at the same level in both areas (around 0.03). Regarding the wage share of household borrowers, the estimated posterior mean is higher in the United States than in the euro area. This implies a lower steady-state ratio of household loans-to-GDP in the euro area than in the United States. Regarding the adjustment costs, the estimated posterior means are somewhat lower in the euro area than in the United States with respect to deposits and capital, and somewhat higher with respect to loans (except for the adjustment cost for loans to entrepreneurs). The inertia parameters for capital adequacy and entrepreneur borrowing constraints, as well as the curvature parameters, are somewhat lower in the euro area than in the United States. These differences in the estimated adjustment costs, inertia and curvature parameters probably reflect structural differences between the two economies. Nevertheless, any comparison of the estimation results should be made with caution, as they might be influenced by the shorter time-series of the euro area.

Tables C.3 and C.5 report the estimated *shock processes*. While covering a wide range of outcomes, the priors are relatively conservative with respect to the importance of financial shocks. As noted by Iacoviello (2015), a combination of default, house price and LTV shocks at the prior mean would account for a relatively small amount of the total output variance. Comparing the posterior means, default shocks appear to be much less persistent in the euro area than in the United States. The LTV shock for entrepreneurs and the technology shock also seem to be much less persistent in the euro area. By contrast, the preference shock is somewhat more persistent in the euro area than in the United States. The housing demand and preference shocks seem to be the most persistent shocks in both the United States and the euro area. With regard to the estimated standard deviations of the shocks, the size of the entrepreneur default shock in the euro area is much greater than in the United States. In contrast, the size of the household borrower default shock is much lower in the euro area, which likely reflects a much lower cyclical volatility of losses on household loans in the euro area. Both findings reflect the relative importance of these channels in the individual economies. Housing demand seems to be not only the most persistent shock in both economies, but also the largest (in the United States it is broadly on a par with the LTV shock for entrepreneurs).

Table C.6 shows the *steady-state* ratios in the two model applications, while Table C.7 contains historical averages of *ratios in the data* for the two economies. Taking into account the calibrated and estimated model parameters, the holding of capital stock at the steady state of the model economy is distributed between entrepreneurs and household savers at a ratio of around 40:60 in the euro area, compared with a ratio of around 30:70 in the United States. Regarding the loan-to-GDP ratio, while total loans in the steady state are higher in the euro area model, this is entirely due to higher entrepreneur loans, whereas in the steady state euro area household loans are somewhat lower than in the United States.

It is worth noting that these steady-state ratios are not directly comparable to the observed historical ratios reported in Table C.7. The model features stylised institutional sectors in which household borrowers and entrepreneurs do not hold financial assets and household savers do not have any debt. Thus, the steady-state ratios relate to the net indebtedness of the sectors, whereas the ratios in the data illustrate gross indebtedness.

With regard to consumption, while the total consumption-to-output ratio is broadly similar in the steady states of the two economies, the distribution reveals important differences: household borrowers and entrepreneurs consume much less in the euro area than in the United States. Finally, the investment-to-output ratio is very similar in the steady states of the two economies and is somewhat above the ratios observed in the data in both cases, which is to be expected given the lack of general government and external sectors in the model.

4.2 Impulse response analysis

Figure C.1 in Appendix C illustrates the model dynamics via the responses of output to estimated model shocks at the mean of the estimated parameter values. The chart compares the output responses in the euro area and the United States to one standard deviation impulses to the eight structural shocks in the original model – as listed in Iacoviello (2015) – and in our benchmark specification, which accounts for capital reallocation inefficiency.

While the responses are qualitatively similar between the two economies in general, the two alternative model specifications display some noteworthy differences. Most importantly, the output response to an *entrepreneur default shock*, which is shown in more detail in Figure C.2, becomes significantly negative in the case of the euro area after incorporating capital reallocation inefficiency. By contrast, this shock produces a small positive impact on output in the original model. The reason for this is that a redistribution of resources from banks to entrepreneurs reduces loan supply (owing to a drop in banks' equity), but this is more than offset by an increase in investment and capital accumulation as the higher net worth of entrepreneurs relaxes their budget constraint. By introducing capital reallocation inefficiency, the increased depreciation from the shock reduces entrepreneur capital, and hence also production capacity, which is associated with lower demand for labour, consumption and output.

A *household default shock*, as illustrated in more detail in Figure C.3, produces unambiguously negative output effects in both economies across the two model versions. The drop in output is more pronounced in the United States. A default by household borrowers relaxes their budget constraint and allows an increase in their consumption and household loans (for a given level of housing collateral) and a reduction in hours worked. However, it puts pressure on banks' balance sheets, reducing their ability to accept deposits and extend loans. As bankers have to deleverage, lending rates rise, whereas loans to entrepreneurs decline. With fewer hours worked, factor complementarities reduce the marginal product of capital, thus exacerbating the decline in output. Overall, the negative impact on output owing to household defaults in the euro area is about one-third of the impact in the United States. This is partly due to the smaller estimated standard deviation of this type of shock in the former case.

Housing preference, investment and *LTV* shocks appear to have similar effects on output in the euro area and the United States. Increased housing demand pushes up house prices, thus relaxing the borrowing constraint for both households and entrepreneurs and leading to increases in loans, output, investment and consumption. Positive LTV shocks for entrepreneurs or households also relax the respective borrowing constraints, leading to increased loans, investment, output and consumption. In the case of LTV shocks for household borrowers, households initially work less and consume more, meaning that investment and output initially drop before going on to rise above the steady state. For both types of LTV shocks, output responses in the euro area and the United States are fairly similar.

Finally, the *TFP* and *preference* shocks lead to a positive output response across model versions and economies. A *TFP* shock increases output, income and consumption, while the resulting higher capital utilisation stimulates investment and demand for loans. House prices rise as households become wealthier, which relaxes the borrowing constraints of entrepreneurs and impatient households. A *preference* shock boosts consumption and housing demand, while capital utilisation and investment jump and loans and total capital increase gradually. Overall, the *TFP* and *preference* shocks are associated with considerably smaller output responses in the euro area than in the US. For these shocks, the estimated standard deviations of the shock processes are smaller for the euro area, resulting in smaller output responses, albeit with the same qualitative transmission mechanisms in place.

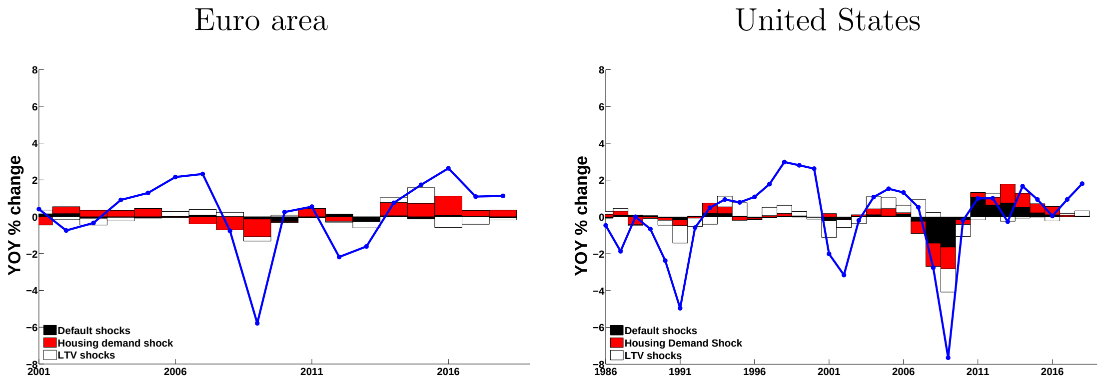
4.3 Financial drivers of business cycles

An important question that the estimated model can answer is how much financial shocks contribute to the business cycle fluctuations in the euro area and the United States. Figure 3 shows the historical decomposition of structural shock contributions to output in the euro area and the United States, focusing on three types of financial shocks: default shock, housing demand shock and LTV shock. While in both cases financial shocks were not the dominant drivers of output prior to 2007, they became very prominent in the United States during the financial crisis and its aftermath and gained importance in the euro area in the course of its double-dip recession and in the subsequent recovery.

Focusing on the results for the euro area, it is interesting to note that the decline in output during the global financial crisis is largely attributable to negative TFP and investment shocks, while the one during the sovereign debt crisis is largely driven by negative preference shocks, as illustrated in Table 1.[6] The former possibly reflects the fact that the global financial crisis started in the United States and initially represented an external shock to the euro area economy. While the housing sectors

[6] These results are also corroborated by the conditional variance decomposition at various forecast horizons (detailed results available from the authors upon request). For both the euro area and the United States, preference and technology shocks seem to explain the bulk of the variance of output and consumption, at both short and long horizons. Of the financial shocks, defaults by entrepreneurs seem more important in explaining the output variance in the euro area than in the United States, whereas defaults by households are important in the United States compared to the euro area. Overall, the importance of financial shocks seems to decline with the length of the horizon of the forecast variance decomposition.

Figure 3 Financial shock contributions to historical fluctuations in real GDP



Notes: The solid lines plot actual data in year-on-year percentage change. The bars show the contributions of the estimated financial shocks. Data are expressed in deviation from their steady-state. The left panel shows the decomposition for the euro area, while the right panel presents that of the United States. A historical decomposition of investment, loans and house prices, with aggregated shocks, can be found in Appendix C.6.

started to deteriorate at broadly the same time in the two economies, the deterioration of the euro area financial sector occurred later and to a smaller extent than in the United States.

Regarding the second leg of the double-dip recession, the model's interpretation of the sovereign debt crisis might reflect the lack of a general government sector meaning that the negative sentiment and resulting decline in output is largely attributed to preferences, in the context of reduced domestic demand. While sovereign financial shocks have undoubtedly played a key role during the sovereign debt crisis in the euro area, a limitation of the model is that this channel is missing. At the same time, negative default, housing, LTV, TFP and investment shocks also contributed to the 2012-13 downturn in the euro area, albeit to a much lesser extent. It is worth noting that default shocks have a small negative impact on growth well after the contraction in economic activity is over, such as in 2010-11 and 2015, which is an indication of the slow and gradual recognition of losses by banks in the euro area. The shock contributions in the historical decomposition also reflect the estimated persistence of the shock processes.

Overall, the model attributes between one-fifth and one-quarter of the decline in euro area output during the double-dip recession to financial factors.[7] These factors contributed more heavily to the euro area recovery between 2014 and 2018, accounting for more than 40% of the upturn and reflecting almost entirely the positive contributions from housing demand shocks.

[7] More specifically, our estimates suggest that financial factors accounted for 27% of the decline in output between 2008 and 2009 and 20% of the decline in output between 2012 and 2013 in the euro area.

Table 1 Historical decomposition of real GDP growth in the euro area and the United States

Euro area														
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.1	0.0	-0.1	-0.3	-0.1	0.1	-0.3	0.1	-0.1	0.1	0.0	-0.1	-0.3	-0.2
Housing Demand shock	-0.4	-0.7	-1.0	-0.1	0.4	-0.2	-0.0	0.7	0.7	1.1	0.3	0.4	-2.1	3.4
LTV shocks	0.3	0.2	-0.2	0.1	0.0	-0.1	-0.3	0.3	0.8	-0.6	-0.4	-0.1	0.4	-0.4
Preference shock	1.1	0.2	-0.3	-1.4	-1.4	-1.7	-1.1	-0.1	1.0	2.4	1.1	1.6	-0.3	2.0
TFP & Inv. shocks	1.1	-0.6	-4.3	1.8	1.5	-0.4	0.0	-0.2	-0.8	-0.4	0.1	-0.7	-1.9	-0.8
All shocks (data)	2.3	-0.8	-5.8	0.3	0.5	-2.2	-1.6	0.8	1.7	2.6	1.1	1.1	-4.0	4.1
United States														
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.2	-1.4	-1.6	-0.1	1.1	0.6	0.8	0.5	0.2	0.1	0.0	0.0	-3.4	3.4
Housing Demand shock	-0.7	-1.3	-1.2	-0.3	0.3	0.4	1.0	0.8	0.5	0.5	0.1	0.0	-3.4	3.5
LTV shocks	0.9	0.2	-1.3	-0.7	-0.2	0.2	-0.2	-0.1	-0.0	-0.2	0.1	0.3	-0.7	-0.1
Preference shock	2.4	1.6	-4.1	0.7	1.0	-1.2	-0.8	0.1	0.3	1.5	0.8	1.7	0.6	3.3
TFP & Inv. shocks	-2.0	-1.9	0.5	0.2	-1.2	0.9	-1.0	0.4	-0.1	-1.8	-0.0	-0.2	-3.1	-3.0
All shocks (data)	0.5	-2.8	-7.6	-0.2	1.0	1.0	-0.3	1.7	0.9	0.0	1.0	1.8	-10.1	7.2

Notes: Contributions of estimated shocks to year-on-year growth in output. Similar tables for consumption and investment can be found in Appendix C.6.

Regarding the results for the United States, the original finding by Iacoviello (2015) that about two-thirds of the 2008-09 downturn in output is attributable to financial factors remains broadly valid after a re-estimation based on our extended dataset and using the modified version of the model which accounts for capital misallocation. Despite slight changes in the de-trending and estimation results (based on the extended series), the financial factors are estimated to have contributed close to two-thirds of the downturn in the Great Recession in the United States. The model results also indicate that around half of the US GDP expansion between 2014 and 2018 is attributable to financial factors. Additional historical decomposition results for a number of key variables are presented in Appendix C.6.

5 Sensitivity of the results

In this section, we report the sensitivity of our results in response to two modifications to the set-up. First, we increase the bank loan charge-offs in the euro area by a fraction of the increase in the stock of non-performing loans. Second, we use utilisation-unadjusted TFP data and a utilisation-augmented measurement equation to check the sensitivity of the results for the United States under the benchmark model.

Appendix D provides a comparison of the dynamic properties of the model between the benchmark results for the euro area and the United States and the impulse responses following these two exercises.

5.1 Sensitivity to bank loan losses

It is well-documented that, following the global financial crisis, the recognition of losses from non-performing loans (NPLs) held on bank balance sheets has been slower and less decisive in the euro area than in the United States. This largely reflects fundamental differences in financial market structures and regulatory incentives (see International Monetary Fund, 2015).

Under-reporting of charge-offs and losses from delinquent loans is more likely to have affected euro area banks, which often carried NPLs on their balance sheets without recognising and quickly writing off the associated losses. This may result in the contribution of default shocks to the downturn in the euro area being underestimated compared with the United States. To deal with this challenge in the data, which is amplified by the lack of official statistics on euro area charge-offs, we increase our charge-off proxy for the euro area by a percentage of the change in the stock of NPLs that banks carry on their balance sheets. In view of evidence in European Central Bank (2016)[8], and in the spirit of the approach proposed by Harris et al. (2018), we add 20% of the increase in the NPL ratios to the calculated charge-off rates, a conservative estimate for the additional loss associated with the increase in the stock of NPLs.

A detailed set of results is reported in Appendix D.1. Overall, the results suggest that adding a small proportion of the change in NPLs to the charge-offs does not change the dynamic properties of the model, although there are small changes to some estimated parameters of the shock processes. In terms of the historical decomposition, the key results for contributions from financial shocks to the business cycle dynamics in the euro area remain broadly the same as in the benchmark model. While the contribution of default shocks to the double-dip recession in the euro area increases slightly, the overall contribution of financial factors to the decline in output remains at around one-quarter. In contrast, they account for around 47% of the upturn between 2014 and 2018. It is worth noting that adding the outlined conservative estimate for the additional loss associated with the increase in the stock of NPLs makes the negative contributions of default shocks to the double-dip euro area recession timelier.

[8] "The resulting gap between the notional gross book value (GBV) and net present value (NPV) of NPLs may be as high as 40-50% of the GBV" (p. 139).

5.2 Validation of results using utilisation unadjusted TFP data

No utilisation-adjusted TFP series are available for the euro area. Therefore, we use unadjusted TFP series and adjust the measurement equation for TFP accordingly, as described in Appendix D.2. To test the validity of this approach, we run a counterfactual analysis for the United States with TFP series unadjusted for utilisation and the correspondingly modified measurement equation. When we compare the results based on this modification to the benchmark results for the United States, we observe slightly stronger contributions from TFP and investment shocks to the Great Recession. Nevertheless, financial shocks continue to account for the bulk of the downturn and the subsequent recovery, albeit to a somewhat smaller degree than in the benchmark model. We conclude that this modification allows for a reasonable approximation of the roles played by both TFP and financial shocks. Indeed, given that utilisation-adjusted TFP series for the euro area are not available, it remains the only viable approach.

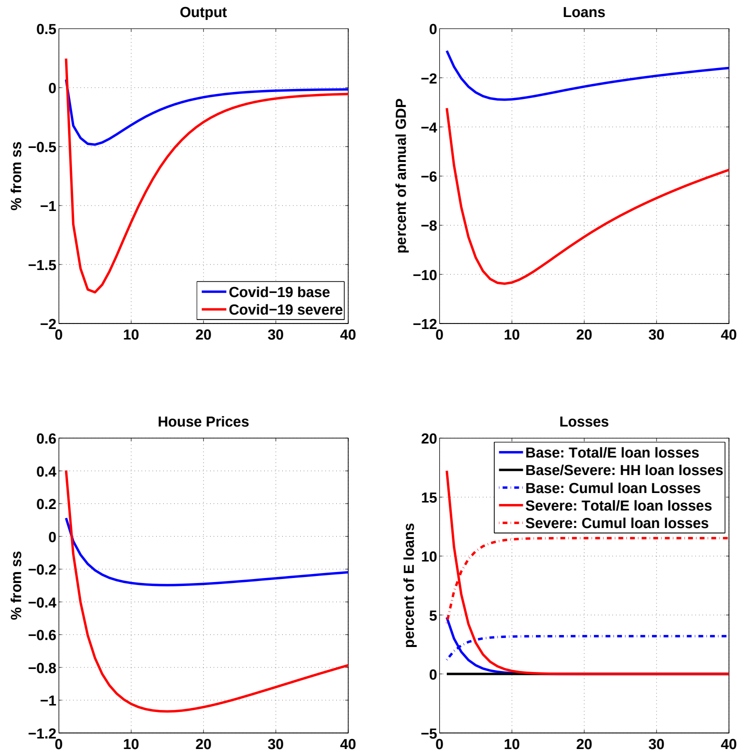
6 Financial amplification effects of the COVID-19 pandemic

The COVID-19 pandemic, together with the associated lockdowns and wide-spread containment measures, triggered unprecedented economic contractions in the euro area and globally in the first half of 2020. As an enormous negative shock to economic activity, this first-round economic damage could be followed by strains on borrowers' finances and rising defaults, transmitted onto banks' balanced sheets via impairments in loan portfolio quality. A widely shared concern at present is that the recovery could be stifled by associated negative second-round financial amplification effects stemming from financial disruptions and reduced credit supply.

This section presents potential financial amplification effects of the COVID-19 pandemic, resulting from scenarios with strong increases in bank losses on NFC loans. Given the focus on financial shocks and frictions, the estimated model is particularly well-suited for evaluating such financially-driven second-round effects.

Utilising the estimated benchmark model for the euro area, we present detailed simulation results of these financial amplification effects in Figure 4. An extended set of results can be found in Figure E.1 in Appendix E. The magnitudes of the entrepreneur default shocks in the two simulations are calibrated to result in cumulative bank losses in a range of 3% to 11.5% of NFC loans. This is based on expected

Figure 4 Impulse responses to a *scenario on potential entrepreneur loan losses* implied by the lockdown measures due to the COVID-19 pandemic in the euro area



Notes: Impulse responses to a scenario on *entrepreneur default loan losses* implied by the lockdown measures due to the COVID-19 pandemic in the euro area. The base scenario assumes cumulative losses of 3%, while the severe scenario assumes losses of up to 11.5%. All responses are expressed in terms of percentage deviations from steady state.

bank loan losses in scenarios with NFC cash-flow disruptions and macroeconomic stress, as presented in European Central Bank (2020).[9] According to the simulations, the expected bank losses are transmitted into output declines ranging from 0.5% to 1.7% at the trough, five quarters after the initial shock. Overall, the results suggest substantial financial amplification risks to real economic activity stemming from second-round effects due to the COVID-19 pandemic.

7 Concluding remarks

A decade on, the US financial sector has recovered from the global financial crisis, while the one in the euro area still suffers from high rates of non-performing loans

[9] For further details see European Central Bank (2020), Financial Stability Review, May, pp. 58-59.

(NPLs), which act as a drag on credit growth and economic activity. Arguably, the impact of the financial sector on real economic activity has increased not only in the Great Recession and its immediate aftermath, but also during normal times. Assessing the impact of financial factors over the business cycle has become a major research question in recent years.

In this paper, we present novel results for the euro area, derived from an estimated DSGE model featuring a banking sector and financial frictions. The model, based on a modification of the "Financial Business Cycles" model originally developed by Iacoviello (2015), allows to disentangle the underlying financial and real drivers of the respective business cycles in the euro area and the United States. The capital reallocation inefficiency we introduce to the original framework results in a more realistic characterisation of entrepreneur default shocks.

One key finding is that financial factors, as represented in this model, seem to play a smaller role in driving the business cycle in the euro area than in the United States. However, it should be noted that this result might reflect in part missing channels, namely foreign financial spillovers and sovereign default risk. Extending the model in directions that explore such channels is a promising avenue for future work.

The set-up of the model allows us to track macro-financial interactions, including possible second-round effects on the economy stemming from bankruptcies and defaults. Applying the model to track financial amplification risks stemming from the COVID-19 pandemic, we find substantial second-round effects on the real economic activity associated with scenarios with a rise in defaults on corporate loans.

A natural way forward is to consider augmenting the model to include nominal rigidities and thus also evaluate the role of monetary policy over the business cycle. Another promising extension is to develop a two-economy version of the model that would allow cross-boarder linkages and international spillovers.

References

An, S. and F. Schorfheide (2007). Bayesian analysis of DSGE models. *Econometric Reviews Vol. 26, No. 2-4: 113–172.*

Bernanke, B. S. (2018). The real effects of disrupted credit: evidence from the global financial crisis. *Brookings Papers on Economic Activity Vol. 49, No. 2: 251–342.*

European Central Bank (2013). *Financial Stability Review.* May.

European Central Bank (2016). *Financial Stability Review.* November.

European Central Bank (2020). *Financial Stability Review.* May.

Fernald, J. (2014). A quarterly, utilization-adjusted series on total factor productivity. Federal Reserve Bank of San Francisco Working Paper 2012-19.

Furlanetto, F., F. Ravazzolo, and S. Sarferaz (2019). Identification of financial factors in economic fluctuations. *The Economic Journal Vol. 129, No. 617: 311–337.*

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010). Credit and banking in a DSGE Model of the euro area. *Journal of Money, Credit and Banking Vol. 42, No. s1: 107–141.*

Guerrieri, L., M. Iacoviello, F. Covas, J. C. Driscoll, M. Jahan-Parvar, M. Kiley, A. Queralto, and J. Sim (2019). Macroeconomic effects of banking-sector losses across structural models. *International Journal of Central Banking Vol. 15, No. 3: 137–204.*

Harris, T. S., U. Khan, and D. Nissim (2018). The expected rate of credit losses on banks' loan portfolios. *The Accounting Review Vol. 93, No. 5: 245–271.*

Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics Vol. 18, Issue 1: 140–163.*

International Monetary Fund (2015). *Global Financial Stability Report.* April, Washington, DC.

Jordá, O., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking Vol. 45, No. s2: 3–28.*

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2019). Credit supply and the housing boom. *Journal of Political Economy Vol. 127, No. 3: 1317–1350.*

Kollmann, R., Z. Enders, and G. J. Müller (2011). Global banking and international business cycles. *European Economic Review Vol. 55, No. 3: 407–426.*

Ramey, V. A. and M. D. Shapiro (2001). Displaced capital: a study of aerospace plant closings. *Journal of Political Economy Vol. 109, No. 5: 958–992.*

Appendix

A Key equations in the model

The representative *patient* (subscript H) and *impatient* (subscript S) **households** choose their consumption C, housing H and working time N to maximise their utility. The objectives for patient and impatient households have the same functional form. In the case of patient households, the objective is the following.

$$\max E_0 \sum_{t=0}^{\infty} \beta_H^t \left(A_{p,t}(1-\eta)\log(C_{H,t} - \eta C_{H,t-1}) + jA_{j,t}A_{p,t}\log H_{H,t} + \tau \log(1 - N_{H,t}) \right), \qquad \text{(A.1)}$$

where β_H^t is the discount factor, $A_{p,t}$ and $A_{j,t}$ denote preference and housing demand shocks, j is the housing preference share, η is the external consumption habit and τ is the weight of leisure in the utility.

The respective patient and impatient household *budget constraints* are as follows.

$$C_{H,t} + \frac{K_{H,t}}{A_{K,t}} + D_t + q_t(H_{H,t} - H_{H,t-1}) + ac_{KH,t} + ac_{DH,t} =$$
$$\left(R_{M,t} z_{KH,t} + \frac{1 - \delta_{KH,t}}{A_{K,t}} \right) K_{H,t-1} + R_{H,t-1} D_{t-1} + W_{H,t} N_{H,t} \qquad \text{(A.2)}$$
$$C_{S,t} + q_t(H_{S,t} - H_{S,t-1}) + R_{S,t-1} L_{S,t-1} - \epsilon_{H,t} + ac_{SS,t} = L_{S,t} + W_{S,t} N_{S,t}, \qquad \text{(A.3)}$$

where D_t are deposits, $ac_{KH,t}$ and $ac_{DH,t}$ represent quadratic adjustment costs for capital and deposits, the corresponding gross returns are denoted by $R_{M,t}$ and $R_{H,t}$, $z_{KH,t}$ is the capital utilisation rate, $\delta_{KH,t}$ is the depreciation function and $W_{,t}$ is the real wage. The impatient household receives loans $L_{S,t-1}$, paying a gross interest rate $R_{S,t-1}$ and being subject to adjustment costs $ac_{SS,t}$. It faces a *borrowing constraint*, limiting its liabilities to a fraction of its housing value.

$$L_{S,t} \leq L_{S,t-1} + (1 - \rho_S) m_S A_{MH,t} E_t \left(\frac{q_{t+1}}{R_{S,t}} H_{S,t} \right) \qquad \text{(A.4)}$$

where ρ_S allows for a slow adjustment of the borrowing constraint, m_S is a loan-to-value (LTV) ratio parameter, $A_{MH,t}$ is a shock to the borrowing capacity of the household and q_{t+1} is the housing price in units of consumption.

Bankers maximise their utility, defined symmetrically to the objective for entrepreneurs, given by equation 1 in the main text, subject to the following *flow-of-funds constraint.*

$$C_{B,t} + R_{H,t-1} D_{t-1} + L_{E,t} + L_{S,t} + ac_{DB,t} + ac_{EB,t} + ac_{SB,t} =$$
$$D_t + R_{E,t} L_{E,t-1} + R_{S,t} L_{S,t-1} - \epsilon_{E,t} - \epsilon_{H,t}, \qquad \text{(A.5)}$$

where $ac_{DB,t}$, $ac_{EB,t}$ and $ac_{SB,t}$ are quadratic adjustment costs paid by the bank for adjusting deposits D_t and loans to entrepreneurs $L_{E,t}$ and to impatient households

$L_{S,t}$, where $\epsilon_{E,t}$ and $\epsilon_{H,t}$ represent the redistribution shocks, which also appear in the budget constraints of the entrepreneur and the impatient household.

Bankers face the following *capital adequacy constraint*, which requires that their equity $(L_t - D_t - E_t\epsilon_{t+1})$ is greater or equal to a fraction $(1-\gamma)$ of their assets $(L_t - E_t\epsilon_{t+1})$, thus limiting their ability to borrow from the patient households.

$$L_t - D_t - E_t\epsilon_{t+1} \geq \rho_D(L_{t-1} - D_{t-1} - E_{t-1}\epsilon_t) + (1-\gamma)(1-\rho_D)(L_t - E_t\epsilon_{t+1}), \tag{A.6}$$

where $L_t = L_{E,t} + L_{S,t}$ are bank loans, $\epsilon_t = \epsilon_{H,t} + \epsilon_{E,t}$ are bank losses, whereas ρ_D allows for a gradual adjustment in bank capital.

Entrepreneurs maximise their objective, given by equation 1 in the main text, subject to a *budget constraint* (given by equation 2 in the main text) and produce final goods Y_t, according to a *production function* (given by equation 3 in the main text). In obtaining loans from the banker, they are subject to the following *borrowing constraint*, which limits their borrowing capacity to a fraction (m_H or m_K) of their collateral, in terms of own real estate ($H_{E,t}$) and capital stock ($K_{E,t}$), after having paid a share (m_N) of the total wage bill in advance.

$$L_{E,t} \leq \rho_E L_{E,t-1} + (1-\rho_E)\, A_{ME,t}\left(m_H E_t\left(\frac{q_{t+1}}{R_{E,t+1}}H_{E,t}\right) + m_K K_{E,t} - m_N(W_{H,t}N_{H,t} + W_{S,t}N_{S,t})\right), \tag{A.7}$$

where $A_{ME,t}$ represents the LTV shock to the entrepreneurs' borrowing capacity and ρ_E allows for a gradual adjustment in loans to entrepreneurs.

The quadratic adjustment costs have the following general form.

$$ac_{AX,t} = \frac{\phi_{AX}}{2}\frac{(A_t - At - 1)^2}{A}, \tag{A.8}$$

where the subscript A stands for the asset (deposit or loan) and X stands for the agent paying the costs (banker, entrepreneur or impatient household). While market clearing is implied by aggregating all budget constraints, the housing market is cleared by the following condition.

$$H_{H,t} + H_{S,t} + H_{E,t} = 1 \tag{A.9}$$

The exogenous shocks follow zero-mean first-order autoregressive (AR(1)) processes, which have the following general form for the default shocks and the remaining shocks, respectively.

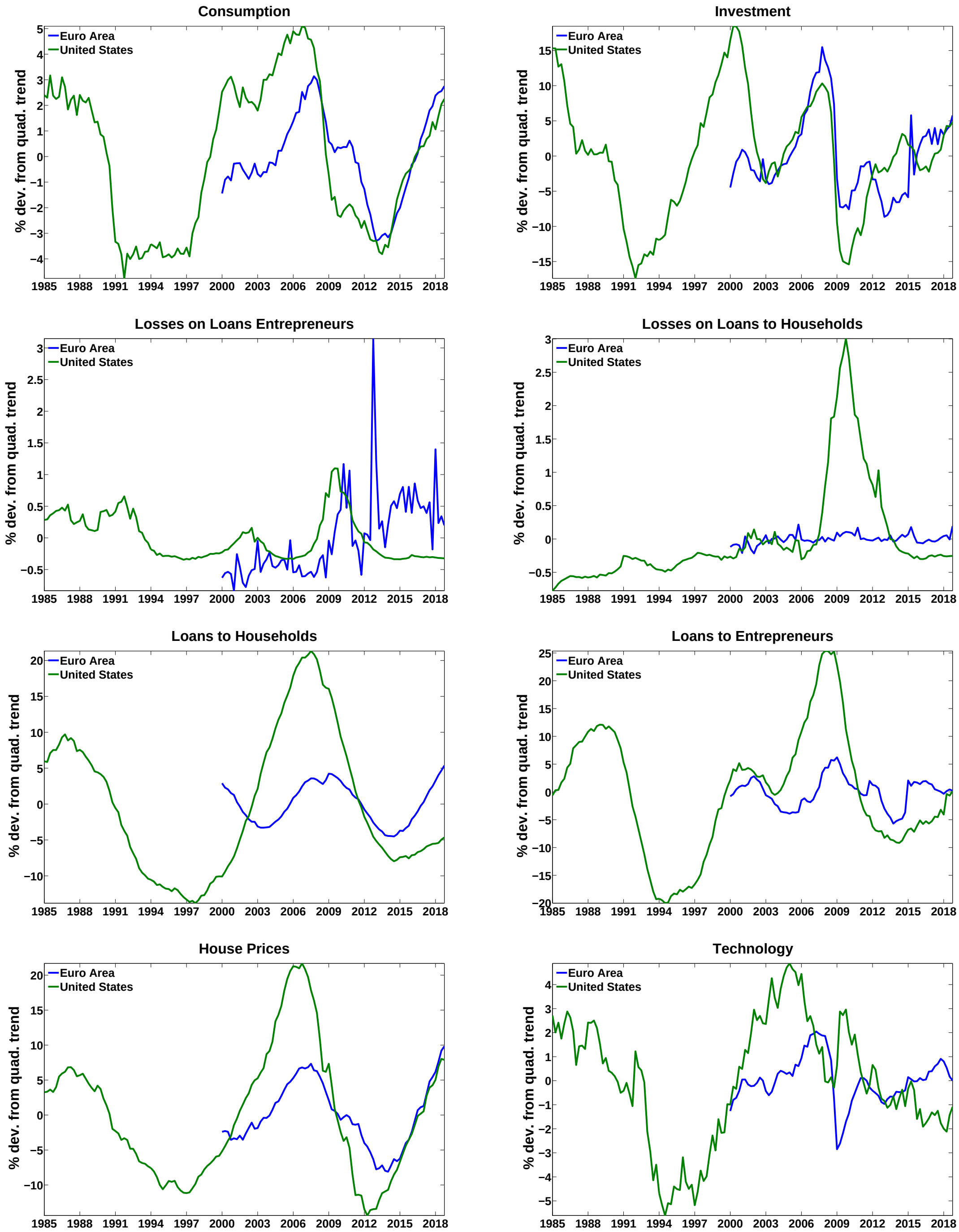
$$\begin{aligned} &\epsilon_{X,t} = \rho_{zh}\epsilon_{X,t-1} + u_{X,t},\ u_X \sim N(0,\sigma_{zx}) \\ &\log A_{z,t} = \rho_j \log A_{z,t-1} + u_{z,t},\ u_z \sim N(0,\sigma_z) \end{aligned} \tag{A.10}$$

where the subscript X stands for the defaulting agent, and z stands for the respective shock.

The above equations, along with those in the main text, are sufficient to understand the model's key specifications and transmission mechanisms. Assuming that the constraints A.4, A.6 and A.7 are always binding the model's dynamics are defined by the linearised system of equations for its equilibrium. A necessary condition for the agents to be financially constrained is that the discount factors for the entrepreneurs and impatient households are lower than the weighted average of the discount factors for the bankers and patient households, while the bankers are more impatient than the savers. For a detailed derivation of the model steady state and dynamic equations, please see Iacoviello (2015).

B Data construction

Figure B.1 Data used in the estimation



Notes: For the euro area the period between 2000 and 2005 serves to initialise the Kalman filter and the parameters are actually estimated using data from 2006:Q1 to 2018:Q4. The parameters for the US model are estimated using data from 1990:Q1 to 2018:Q4, while the period between 1985 and 1989 serves to initialise the Kalman filter. Technology is capital-utilisation adjusted for the United States, but not for the euro area.

The construction of the quarterly datasets for the United States and the euro area closely follows the methods used by Iacoviello (2015). The quarterly data for the United States covers the period from 1985 to 2018, whereas for the euro area it spans from 2000 to 2018. The first five years of each respective sample are used as a training sample for the initialisation of the Kalman filter. More details on the sources for the eight observable variables for the euro area are given below (with series aliases based on codes from Haver Analytics or the ECB's Statistical Data Warehouse, SDW).

Consumption: (J025PCT@EUDATA): EA19: Final consumption expenditure by households and non-profit institutions serving households, (seasonally and working-day adjusted data, Mil.Ch.10.EUR). The series is log transformed and detrended with a quadratic trend.

Investment: Real private non-residential investment is calculated as a residual by subtracting general government investment and housing investment from gross fixed capital formation. The series is log transformed and detrended with a quadratic trend. The respective series are:
(J025IFT@EUDATA): EA19: Gross Fixed Capital Formation (seasonally and working-day adjusted data, Mil.Ch.2010.EUR);
sa(H025GP51@EUDATA): EA19: General Government: Gross Fixed Capital Formation (NSA, Mil.EUR) - Seasonal Adjustment, all), deflated by the non-housing gross fixed capital formation deflator;
(J025IFHT@EUDATA): EA19: Gross Fixed Capital Formation: Dwellings (seasonally and working-day adjusted data, Mil.Ch.10.EUR).
We linearly smooth the business investment observation for 2015 Q2, which is treated as an outlier, reflecting specific transactions not related to real economic activity.

Losses on loans to entrepreneurs: The series is constructed by multiplying the bank charge-off rates on NFC loans by the volume of loans held by the NFCs. The charge-off rates are calculated from the bank write-offs and the MFI loans to NFCs. The bank write-off flows are scaled by steady-state GDP (where the steady-state is approximated by a cubic trend in the sum of nominal consumption and investment). The respective series are:
sa(M023MWN@EUDATA): EA 11-19: MFIs: Write-offs/write-downs of Loans to NFCs (NSA, Bil.EUR) - Seasonal Adjustment, All;
(M023BNLT@EUDATA): EA: MFI excluding Eurosystem Loans to EA NFCs (EOP, NSA, Mil.EUR);
sa(H025NE4@EUDATA): EA19: NFCs: Balance Sheet: Liabilities: Loans(EOP, NSA, Mil.EUR) - Seasonal Adjustment, All.

There is a one-off spike in losses on loans to entrepreneurs in 2012 Q4, which reflects the transfer of NPLs to the Spanish “bad bank” Sareb.[10]

Losses on loans to households: The series is constructed by multiplying the bank charge-off rates on household loans by the volume of loans held by the household sector. The charge-off rates are calculated from the bank write-offs and the MFI loans to households. The bank write-off flows are scaled by steady-state GDP (where the steady-state is approximated by a cubic trend in the sum of nominal consumption and investment). The respective series are:
(sa(M023MWC@EUDATA)+sa(M023MWM@EUDATA)+sa(M023MWO@EUDATA)): M023MWC: EA 11-19: MFIs: Write-offs/write-downs of Loans to households: Cons Credit (NSA, Bil.EUR); M023MWM: EA 11-19: MFIs: Write-offs/write-downs of Loans to households: Mortgages (NSA, Bil.EUR); M023MWO: EA 11-19: MFIs: Write-offs/write-downs of Loans to households: Other Lending.
(M023BHLT@EUDATA): EA: MFI excluding Eurosystem Loans to EA Households (EOP, NSA, Mil.EUR).
sa(H025HE4@EUDATA): EA19: Households: Balance Sheet: Liabilities: Loans(EOP, NSA, Mil.EUR) - Seasonal Adjustment, All.

Loans to entrepreneurs: The seasonally adjusted data are converted into real terms using the GDP deflator, log transformed and detrended with a quadratic trend. The source is:
sa(H025NE4@EUDATA): EA19: NFCs: Balance Sheet: Liabilities: Loans (EOP, NSA, Mil.EUR) - Seasonal Adjustment, All.

Loans to households: The seasonally adjusted data are converted into real terms using the GDP deflator, log transformed and detrended with a quadratic trend. The source is:
sa(H025HE4@EUDATA): EA19: Households: Balance Sheet: Liabilities: Loans (EOP, NSA, Mil.EUR) - Seasonal Adjustment, All.

House prices: The series is converted into real terms using the GDP deflator, log transformed and detrended with a quadratic trend. The source is:
(Q025PWTE@EUDATA): EA19: Residential Property Price: New & Existing Dwellings (NSA, 2007=100).

TFP: The series is calculated as a residual from a Cobb-Douglas production function (utilising the long-term average labour income share, ν). It is integrated back to levels, log transformed, and detrended with a quadratic trend. The calculation,

[10] For further details see European Central Bank (2013), Financial Stability Review, May, p. 63.

based on the Cobb-Douglas production function, uses the following formulas and is based on the following inputs (using SDW codes), with all variables, except the ratios, expressed in logs:

$$TFP = Y - \nu * (LAN + LAX + log(1 - UNR) + AHN) - (1 - \nu) * K, \qquad \text{(B.1)}$$

where $LAX = LFN - LAN$ and $AHN = LHN - LNN$, where LAX is the labour participation ratio, LFN - is labour force size, LAN - is population size, AHN - is average hours worked, LHN - is total hours worked, and LNN - employment.

Y: MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N: GDP at market prices, chain-linked volume (at 2015 prices), calendar and seasonally adjusted data.

ν: AME.A.EA19.1.0.0.0.ALCD2: adjusted wage share as a percentage of GDP at current factor cost, average over the period 1998-2018.

UNR: STS.Q.I8.S.UNEH.RTT000.4.000: Unemployment rate (as a percentage of labour force), seasonally adjusted.

K: AME.A.EA19.1.0.0.0.OKND: Net capital stock at 2015 prices: total economy; interpolated to quarterly series using the shape-preserving, piece-wise cubic interpolation.

LAN: AME.A.EA19.1.0.0.0.NPAN1: Population: incudes people from 15 to 74 years of age, data measured in thousands of persons, interpolated to quarterly series using the shape-preserving, piece-wise cubic interpolation.

C Additional results for the benchmark model

C.1 Calibrated parameters

Table C.1 Calibrated parameters

Parameter			Value
Household-saver (HS) discount factor	β_H	BETAH	0.9925
Household-borrower (HB) discount factor	β_S	BETAS	0.94
Banker discount factor	β_B	BETAB	0.945
Entrepreneur (E) discount factor	β_E	BETAE	0.94
Total capital share in production	α	ALPHA	0.35
Loan-to-value ratio on housing, HB	m_S	MS	0.9
Loan-to-value ratio on housing, E	m_H	MH	0.9
Loan-to-value ratio on capital, E	m_K	MK	0.9
Wage bill paid in advance	m_N	MN	1.0
Liabilities to assets ratio for Banker, E	γ_E	GAMMAE	0.9
Liabilities to assets ratio for Banker, HB	γ_S	GAMMES	0.9
Housing preference share	$\jmath$	JEI	0.075
Capital depreciation rates	δ_{KE}, δ_{KH}	DELTA	0.035
Capital depreciation due to E defaults	δ_ϵ	DELTAE	0.65
Labour supply parameter, HS	τ_H	TAUH	2.0
Labour supply parameter, HB	τ_S	TAUS	2.0

C.2 Estimated structural and shock parameters

Table C.2 Estimated structural parameters: Euro area

Parameter			Density	Prior distribution		Posterior distribution	
				Mean	St.dev.	Mean	St.dev.
Habit in consumption	η	ECH	Beta	0.50	0.150	0.439	0.0615
D adj. cost, Banks	ϕ_{DB}	FIDB	Gamma	0.25	0.125	0.138	0.0658
D adj. cost, HH saver	ϕ_{DH}	FIDH	Gamma	0.25	0.125	0.066	0.0224
K adj. cost, Entrepreneurs	ϕ_{KE}	FIKE	Gamma	1.00	0.500	0.453	0.1151
K adj. cost, HH saver	ϕ_{KH}	FIKH	Gamma	1.00	0.500	1.329	0.5978
Loans to E, adj. cost, Banks	ϕ_{EB}	FILOEB	Gamma	0.25	0.125	0.086	0.0366
Loans to E, adj. cost, E	ϕ_{EE}	FILOEE	Gamma	0.25	0.125	0.038	0.0137
Loans to HB, adj. cost, Banks	ϕ_{SB}	FILOSB	Gamma	0.25	0.125	0.758	0.2738
Loans to HB, adj. cost, HH Borrower HB	ϕ_{SS}	FILOSS	Gamma	0.25	0.125	0.415	0.1710
Capital share of E	μ	MIU	Beta	0.50	0.100	0.445	0.0804
Housing share of E	ν	NU	Beta	0.04	0.010	0.033	0.0055
Inertia in capital adequacy constraint	ρ_D	RHOD	Beta	0.25	0.100	0.181	0.0769
Inertia in E borrowing constraint	ρ_E	RHOE	Beta	0.25	0.100	0.535	0.0859
Inertia in HB borrowing constraint	ρ_S	RHOS	Beta	0.25	0.100	0.753	0.0436
Wage share HB	σ	SIGMA	Beta	0.30	0.100	0.252	0.0672
Curvature for utilization function E	ζ_E	ZETAE	Beta	0.20	0.100	0.255	0.1163
Curvature for utilization function HS	ζ_H	ZETAH	Beta	0.20	0.100	0.369	0.1352

Table C.3 Estimation shock processes: Euro area

Parameter			Density	Prior distribution		Posterior distribution	
				Mean	St.dev.	Mean	St.dev.
Autocor E default shock	ρ_{be}	ZRHO_ABE	Beta	0.80	0.10	0.626	0.1036
Autocor HB default shock	ρ_{bh}	ZRHO_ABH	Beta	0.80	0.10	0.637	0.1097
Autocor housing demand shock	ρ_j	ZRHO_AJ	Beta	0.80	0.10	0.987	0.0045
Autocor investment shock	ρ_j	ZRHO_AK	Beta	0.80	0.10	0.866	0.0588
Autocor LTV shock, E	ρ_{me}	ZRHO_AME	Beta	0.80	0.10	0.446	0.0829
Autocor LTV shock, HB	ρ_{mh}	ZRHO_AMH	Beta	0.80	0.10	0.877	0.0471
Autocor preference shock	ρ_p	ZRHO_AP	Beta	0.80	0.10	0.996	0.0013
Autocor technology shock	ρ_z	ZRHO_AZ	Beta	0.80	0.10	0.905	0.0329
St.dev., default shock, E	σ_{be}	eps_be	InvG	0.0025	0.0250	0.0059	0.0005
St.dev., default shock, HB	σ_{bh}	eps_bh	InvG	0.0025	0.0250	0.0007	0.0001
St.dev., housing demand shock	σ_j	eps_j	InvG	0.0500	0.0500	0.0303	0.0060
St.dev., investment shock	σ_k	eps_k	InvG	0.0050	0.0250	0.0050	0.0008
St.dev., LTV shock, E	σ_{me}	eps_me	InvG	0.0025	0.0250	0.0146	0.0029
St.dev., LTV shock, HB	σ_{mh}	eps_mh	InvG	0.0025	0.0250	0.0119	0.0020
St.dev., preference shock	σ_p	eps_p	InvG	0.0050	0.0250	0.0114	0.0011
St.dev., technology shock	σ_z	eps_z	InvG	0.0050	0.0250	0.0031	0.0003

Table C.4 Estimation structural parameters: United States

Parameter			Density	Prior distribution		Posterior distribution	
				Mean	St.dev.	Mean	St.dev.
Habit in consumption	η	ECH	Beta	0.50	0.150	0.471	0.0511
D adj. cost, Banks	ϕ_{DB}	FIDB	Gamma	0.25	0.125	0.161	0.0838
D adj. cost, HH saver	ϕ_{DH}	FIDH	Gamma	0.25	0.125	0.117	0.0298
K adj. cost, Entrepreneurs	ϕ_{KE}	FIKE	Gamma	1.00	0.500	0.827	0.1574
K adj. cost, HH saver	ϕ_{KH}	FIKH	Gamma	1.00	0.500	2.426	0.3371
Loans to E, adj. cost, Banks	ϕ_{EB}	FILOEB	Gamma	0.25	0.125	0.078	0.0362
Loans to E, adj. cost, E	ϕ_{EE}	FILOEE	Gamma	0.25	0.125	0.066	0.0212
Loans to HB, adj. cost, Banks	ϕ_{SB}	FILOSB	Gamma	0.25	0.125	0.631	0.1606
Loans to HB, adj. cost, HH Borrower HB	ϕ_{SS}	FILOSS	Gamma	0.25	0.125	0.348	0.1437
Capital share of E	μ	MIU	Beta	0.50	0.100	0.370	0.0583
Housing share of E	ν	NU	Beta	0.04	0.010	0.031	0.0074
Inertia in capital adequacy constraint	ρ_D	RHOD	Beta	0.25	0.100	0.239	0.0980
Inertia in E borrowing constraint	ρ_E	RHOE	Beta	0.25	0.100	0.736	0.0905
Inertia in HB borrowing constraint	ρ_S	RHOS	Beta	0.25	0.100	0.714	0.0333
Wage share HB	σ	SIGMA	Beta	0.30	0.100	0.351	0.0561
Curvature for utilization function E	ζ_E	ZETAE	Beta	0.20	0.100	0.376	0.1437
Curvature for utilization function HS	ζ_H	ZETAH	Beta	0.20	0.100	0.465	0.1372

Table C.5 Estimation shock processes: United States

Parameter			Density	Prior distribution		Posterior distribution	
				Mean	St.dev.	Mean	St.dev.
Autocor E default shock	ρ_{be}	ZRHO_ABE	Beta	0.80	0.10	0.954	0.0178
Autocor HB default shock	ρ_{bh}	ZRHO_ABH	Beta	0.80	0.10	0.959	0.0147
Autocor housing demand shock	ρ_j	ZRHO_AJ	Beta	0.80	0.10	0.993	0.0026
Autocor investment shock	ρ_j	ZRHO_AK	Beta	0.80	0.10	0.933	0.0309
Autocor LTV shock, E	ρ_{me}	ZRHO_AME	Beta	0.80	0.10	0.761	0.0867
Autocor LTV shock, HB	ρ_{mh}	ZRHO_AMH	Beta	0.80	0.10	0.873	0.0696
Autocor preference shock	ρ_p	ZRHO_AP	Beta	0.80	0.10	0.982	0.0017
Autocor technology shock	ρ_z	ZRHO_AZ	Beta	0.80	0.10	0.982	0.0039
St.dev., default shock, E	σ_{be}	eps_be	InvG	0.0025	0.0250	0.0008	0.0000
St.dev., default shock, HB	σ_{bh}	eps_bh	InvG	0.0025	0.0250	0.0015	0.0001
St.dev., housing demand shock	σ_j	eps_j	InvG	0.0500	0.0500	0.0322	0.0050
St.dev., investment shock	σ_k	eps_k	InvG	0.0050	0.0250	0.0104	0.0014
St.dev., LTV shock, E	σ_{me}	eps_me	InvG	0.0025	0.0250	0.0332	0.0070
St.dev., LTV shock, HB	σ_{mh}	eps_mh	InvG	0.0025	0.0250	0.0121	0.0015
St.dev., preference shock	σ_p	eps_p	InvG	0.0050	0.0250	0.0184	0.0012
St.dev., technology shock	σ_z	eps_z	InvG	0.0050	0.0250	0.0069	0.0004

C.3 Models' steady-states

Table C.6 Steady-state ratios

(in percent)	EA	US
Capital stock to GDP ratio	184.07	184.13
Ratio of Entrepreneurs in capital stock holding	37.99	29.66
Ratio of HH Savers in capital stock holding	62.0	70.34
Housing stock to GDP ratio (H=1; H/Y*100)	160.98	159.37
HH borrowers' share in housing stock	6.36	10.07
HH savers' share in housing stock	70.75	68.60
Entrepreneurs' share in housing stock	22.89	21.33
Interest rate on deposits (rh)	3.06	3.06
Interest rate on loans (re)	5.12	5.11
Total loans to GDP ratio	93.01	77.19
Entrepreneur loans to GDP ratio	83.41	63.91
Household loans to GDP ratio	9.60	13.28
Consumption to Output	74.23	74.22
Investment to Output	25.77	25.78
HH borrowers' consumption to total consumption	18.45	24.40
HH savers' consumption to total consumption	64.74	54.86
Entrepreneurs' consumption to total consumption	13.92	18.35
Bankers' consumption to total consumption	2.89	2.39
Borrowers' consumption to total HH consumption	22.18	30.79

C.4 Ratios in the data

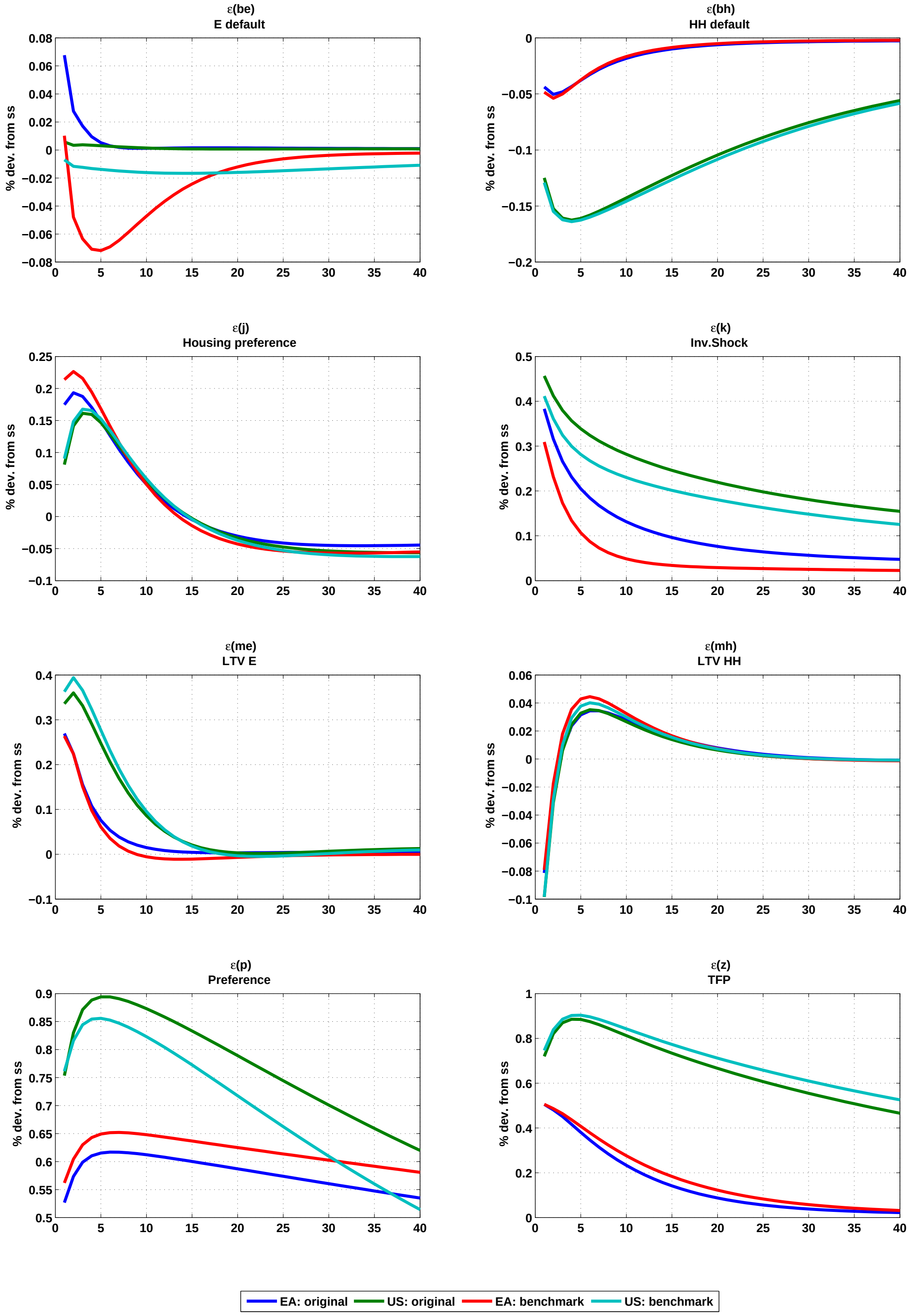
Table C.7 Descriptive statistics

(mean values, in percent)

Variable	EA	US
NFC loans to GDP	125.04	48.86
Charge-off rate for NFC loans (annualised)	0.72	0.76
NFC charge-offs to SS GDP	0.94	0.39
HH loans to GDP	83.71	84.76
Charge-off rate for HH loans (annualised)	0.32	0.85
HH charge-offs to SS GDP	0.27	0.78
Total loans (HH+NFC) to GDP	208.75	133.62
Consumption to GDP ratio	81.62	83.69
Investment to GDP ratio	18.38	16.31

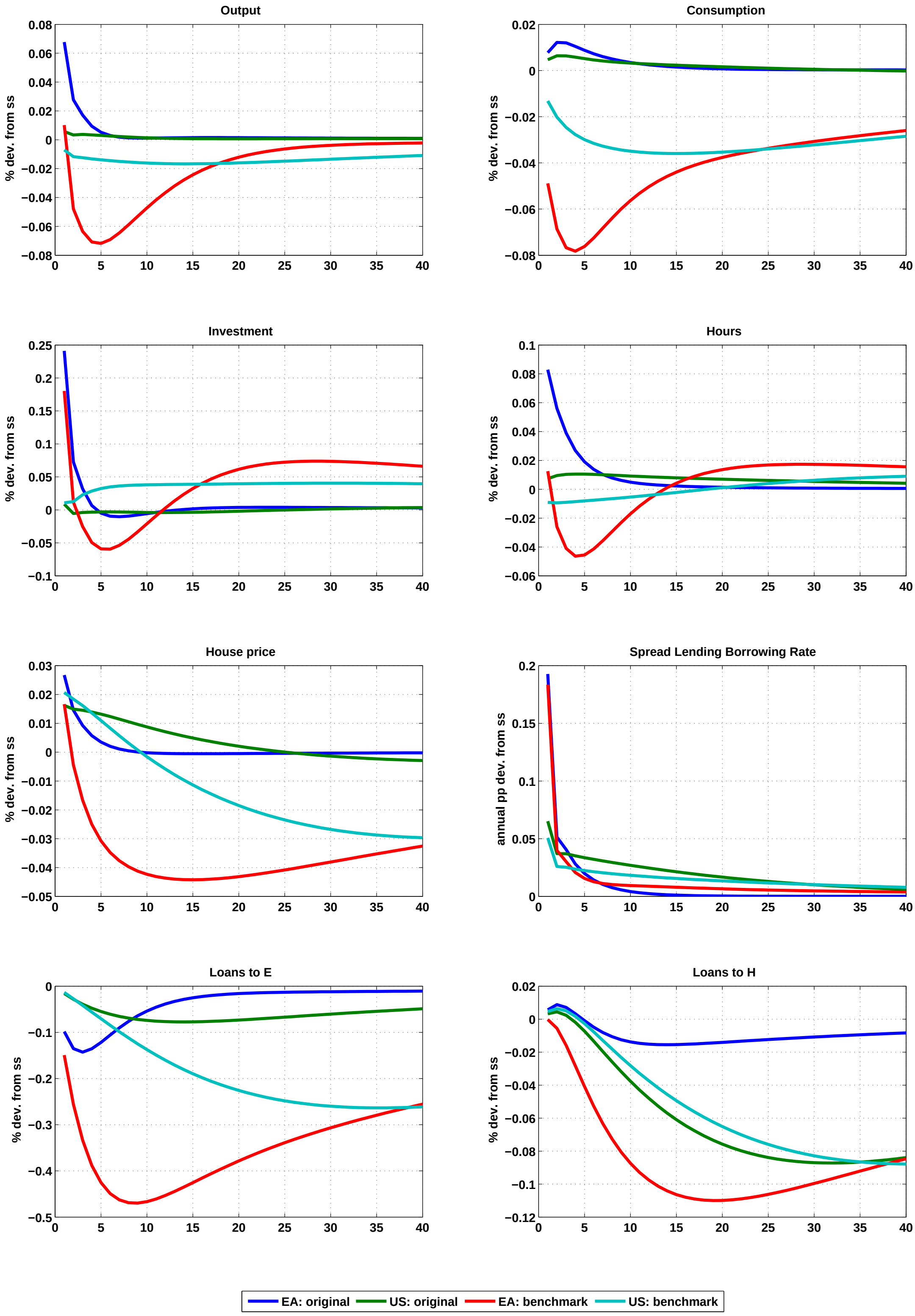
C.5 Impulse responses

Figure C.1 Reaction of *output* in response to one standard deviation shocks in two model versions for the EA and the US



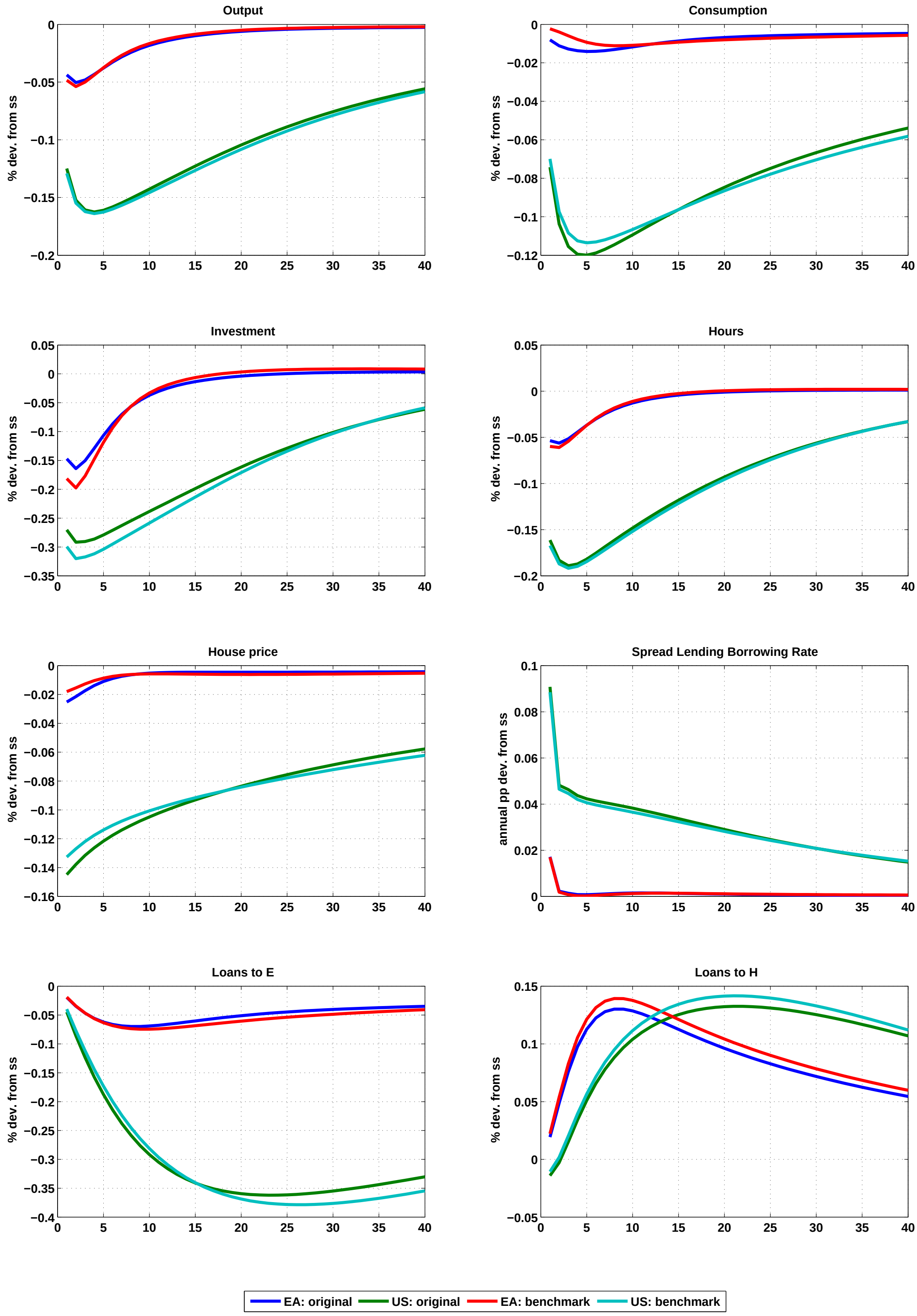
Notes: For the EA and the US, *"original"* display the impulse responses for the original model, as in Iacoviello (2015). For the EA and the US *"benchmark"* show the impulse responses for the benchmark model, which accounts for capital reallocation inefficiency. All responses are in percentage deviations from steady state.

Figure C.2 Impulse response to an estimated one standard deviation *entrepreneur default shock* in two model versions for the EA and the US



Notes: For the EA and the US, *"original M"* display the impulse responses for the model, as in Iacoviello (2015). For the EA and the US *"benchmark"* show the impulse responses for the benchmark model, which accounts for capital reallocation inefficiency. All responses are in percentage deviations from steady state.

Figure C.3 Impulse response to an estimated one standard deviation *household default shock* in two model versions for the EA and the US



Notes: For the EA and the US, *"original M"* display the impulse responses for the model, as in Iacoviello (2015). For the EA and the US *"benchmark"* show the impulse responses for the benchmark model, which accounts for capital reallocation inefficiency. All responses are in percentage deviations from steady state.

C.6 Historical decomposition

Table C.8 Historical decomposition: Euro area

Output	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.1	0.0	-0.1	-0.3	-0.1	0.1	-0.3	0.1	-0.1	0.1	0.0	-0.1	-0.3	-0.2
Housing Demand shock	-0.4	-0.7	-1.0	-0.1	0.4	-0.2	-0.0	0.7	0.7	1.1	0.3	0.4	-2.1	3.4
LTV shocks	0.3	0.2	-0.2	0.1	0.0	-0.1	-0.3	0.3	0.8	-0.6	-0.4	-0.1	0.4	-0.4
Preference shock	1.1	0.2	-0.3	-1.4	-1.4	-1.7	-1.1	-0.1	1.0	2.4	1.1	1.6	-0.3	2.0
TFP & Inv. shocks	1.1	-0.6	-4.3	1.8	1.5	-0.4	0.0	-0.2	-0.8	-0.4	0.1	-0.7	-1.9	-0.8
All shocks (data)	2.3	-0.8	-5.8	0.3	0.5	-2.2	-1.6	0.8	1.7	2.6	1.1	1.1	-4.0	4.1
Investment	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.1	-0.1	-0.3	-0.3	-0.1	0.7	-0.4	0.2	-0.1	0.5	0.1	-0.1	-0.6	0.7
Housing Demand shock	-0.9	-1.8	-2.5	-0.5	1.0	-0.4	-0.0	1.7	1.9	2.7	1.1	1.0	-5.7	8.9
LTV shocks	1.3	1.3	-1.1	0.4	-0.1	-0.2	-1.6	0.8	3.6	-2.0	-1.8	-0.6	1.9	-2.0
Preference shock	1.3	-0.0	-0.4	-1.6	-1.9	-1.9	-1.0	0.0	1.5	2.9	1.1	2.3	-0.8	3.1
TFP & Inv. shocks	4.3	-0.9	-13.0	2.9	5.2	-1.5	-0.0	-1.0	-4.1	1.8	-0.4	-1.1	-6.7	-1.1
All shocks (data)	6.4	-1.4	-17.3	0.9	4.1	-3.4	-3.1	1.7	2.9	5.9	0.1	1.5	-11.4	9.7
Consumption	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.1	0.0	-0.1	-0.2	-0.0	-0.0	-0.2	0.0	-0.1	-0.1	-0.0	-0.1	-0.2	-0.5
Housing Demand shock	-0.2	-0.3	-0.4	0.1	0.3	-0.2	0.0	0.4	0.3	0.5	0.1	0.2	-0.9	1.5
LTV shocks	-0.1	-0.1	0.1	-0.0	0.0	0.0	0.1	0.1	-0.1	-0.1	0.1	0.1	-0.2	0.1
Preference shock	1.0	0.3	-0.2	-1.3	-1.2	-1.6	-1.1	-0.1	0.9	2.3	1.1	1.3	-0.1	1.6
TFP & Inv. shocks	0.0	-0.5	-1.2	1.4	0.2	0.0	0.0	0.0	0.4	-1.1	0.2	-0.5	-0.2	-0.7
All shocks (data)	0.9	-0.6	-1.8	0.0	-0.7	-1.8	-1.1	0.4	1.3	1.5	1.4	1.0	-1.4	2.1

Table C.9 Historical decomposition: United States

Output	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.2	-1.4	-1.6	-0.1	1.1	0.6	0.8	0.5	0.2	0.1	0.0	0.0	-3.4	3.4
Housing Demand shock	-0.7	-1.3	-1.2	-0.3	0.3	0.4	1.0	0.8	0.5	0.5	0.1	0.0	-3.4	3.5
LTV shocks	0.9	0.2	-1.3	-0.7	-0.2	0.2	-0.2	-0.1	-0.0	-0.2	0.1	0.3	-0.7	-0.1
Preference shock	2.4	1.6	-4.1	0.7	1.0	-1.2	-0.8	0.1	0.3	1.5	0.8	1.7	0.6	3.3
TFP & Inv. shocks	-2.0	-1.9	0.5	0.2	-1.2	0.9	-1.0	0.4	-0.1	-1.8	-0.0	-0.2	-3.1	-3.0
All shocks (data)	0.5	-2.8	-7.6	-0.2	1.0	1.0	-0.3	1.7	0.9	0.0	1.0	1.8	-10.1	7.2
Investment	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.5	-2.7	-2.5	0.4	2.0	1.0	1.4	0.8	0.3	0.2	-0.1	-0.0	-5.2	5.7
Housing Demand shock	-0.3	-1.4	-2.0	-1.6	0.3	0.3	1.1	1.5	1.0	0.8	0.5	0.0	-5.3	5.6
LTV shocks	2.9	1.2	-3.3	-2.3	-1.6	0.6	-0.5	-0.3	-0.1	-0.6	0.3	1.0	-1.6	-1.3
Preference shock	1.9	0.8	-4.7	2.5	0.3	-1.4	-0.7	0.7	0.1	1.6	0.5	1.6	0.4	2.7
TFP & Inv. shocks	-1.1	-1.1	-6.9	1.8	3.7	5.1	-0.6	1.1	-2.6	-4.3	0.1	0.7	-7.3	3.0
All shocks (data)	2.8	-3.2	-19.4	0.8	4.8	5.7	0.7	3.7	-1.3	-2.4	1.3	3.3	-19.0	15.8
Consumption	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.1	-1.0	-1.4	-0.3	0.7	0.5	0.5	0.4	0.2	0.1	0.0	0.1	-2.8	2.6
Housing Demand shock	-0.8	-1.2	-0.9	0.2	0.2	0.5	1.0	0.5	0.3	0.3	-0.0	0.0	-2.7	2.8
LTV shocks	0.3	-0.1	-0.5	-0.1	0.3	0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	-0.4	0.3
Preference shock	2.6	1.8	-3.9	0.1	1.2	-1.1	-0.8	-0.1	0.4	1.5	0.9	1.7	0.7	3.5
TFP & Inv. shocks	-2.2	-2.1	3.1	-0.4	-2.8	-0.6	-1.1	0.1	0.8	-0.9	-0.0	-0.5	-1.7	-5.0
All shocks (data)	-0.3	-2.6	-3.6	-0.5	-0.3	-0.6	-0.6	0.9	1.7	0.9	0.8	1.3	-7.0	4.2

Figure C.4 Investment

Euro area | United States

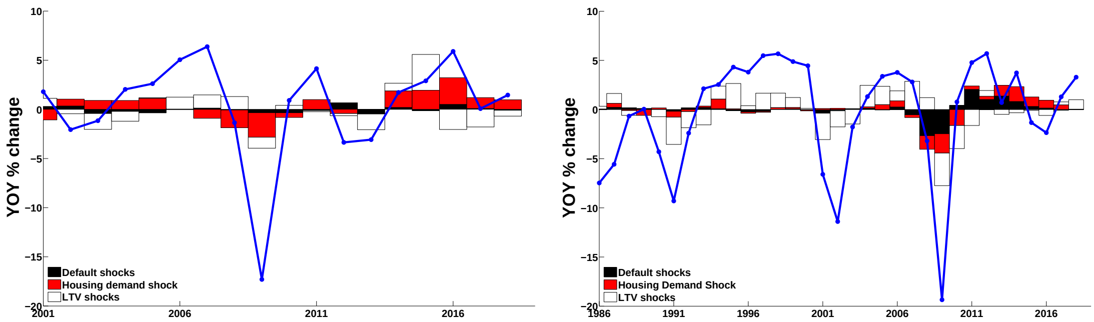


Figure C.5 Loans

Euro area | United States

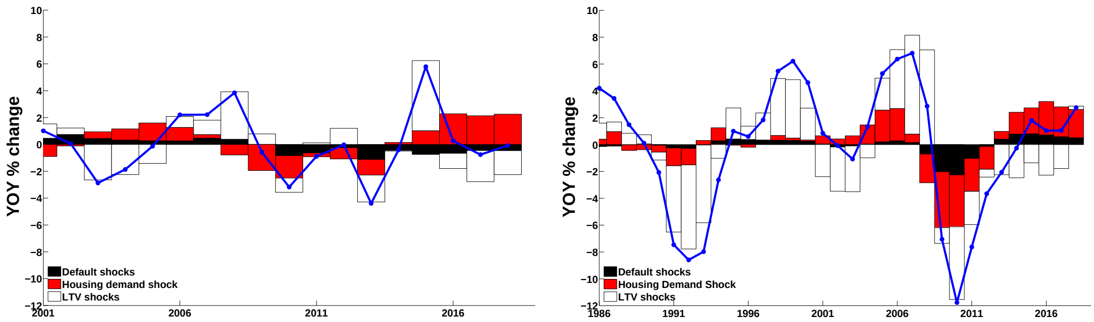
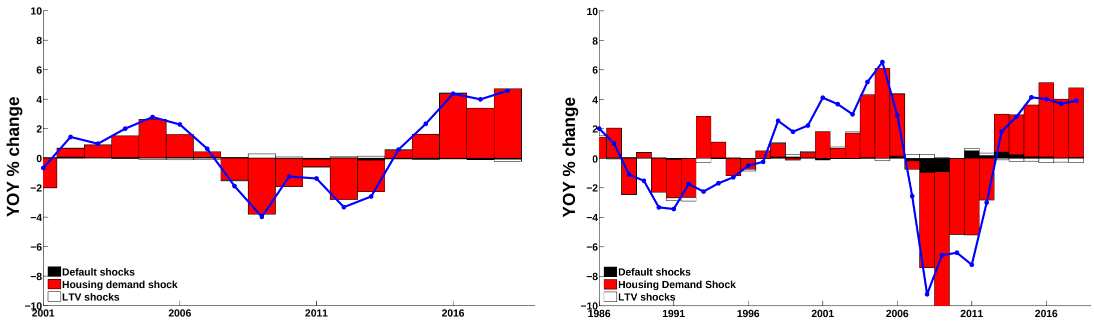


Figure C.6 House prices

Euro area | United States



Notes: The solid lines plot actual data. The bars show the contributions of the estimated financial shocks. Data are expressed in terms of percentage deviation from their mean.

Figure C.7 Real GDP

Euro area | United States

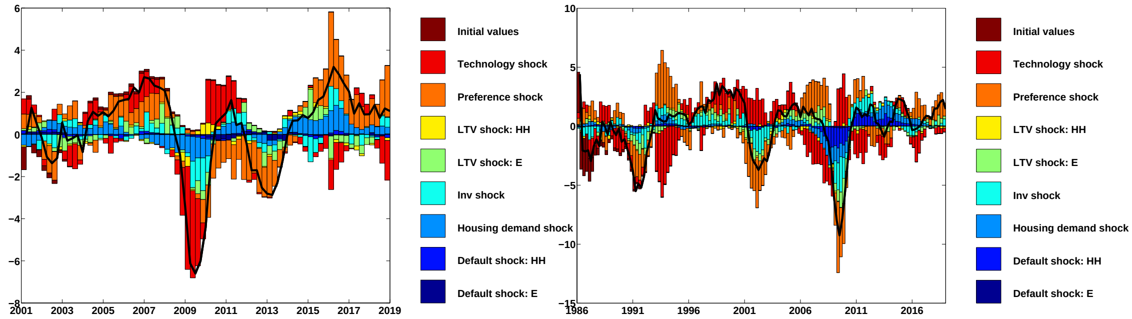


Figure C.8 Consumption

Euro area | United States

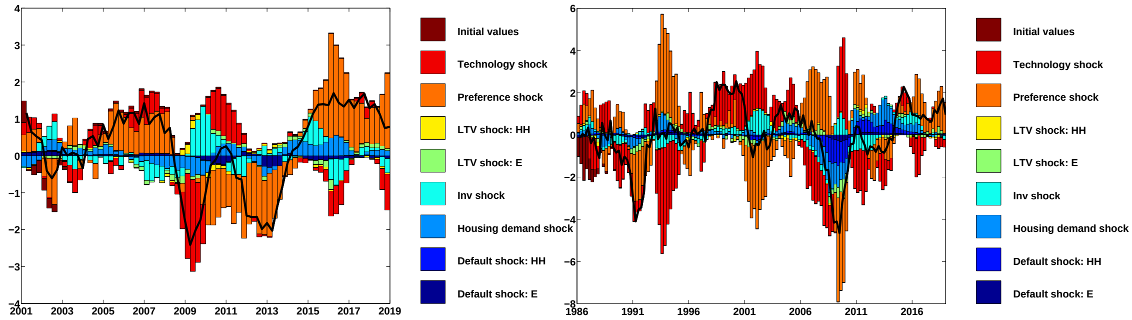
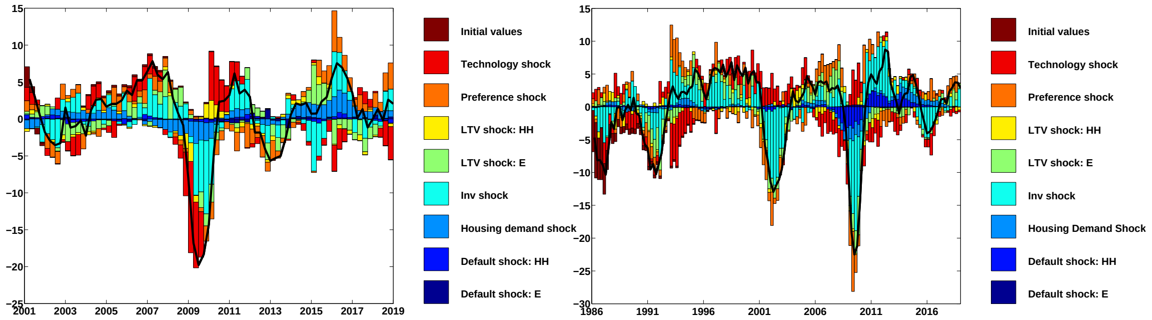


Figure C.9 Investment

Euro area | United States



Notes: The solid lines plot actual data. The bars show the contributions of the estimated financial shocks. Data are expressed in terms of percentage deviation from their mean.

Figure C.10 Total Loans

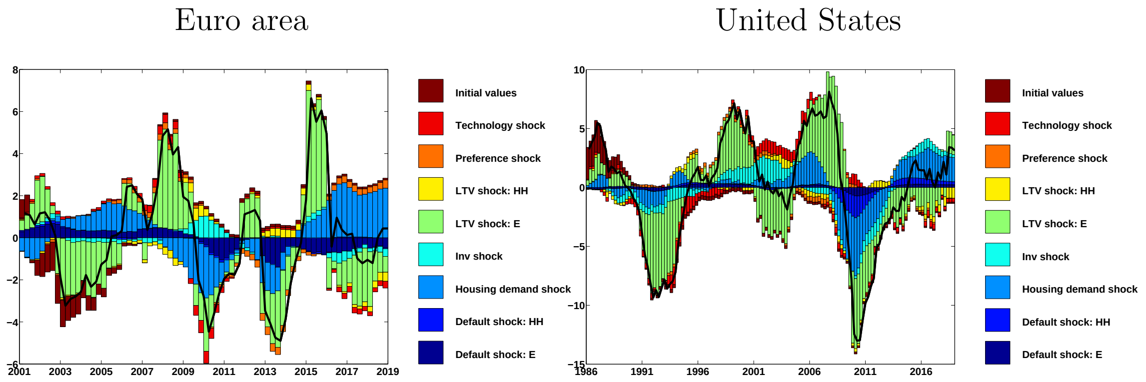


Figure C.11 Loans E

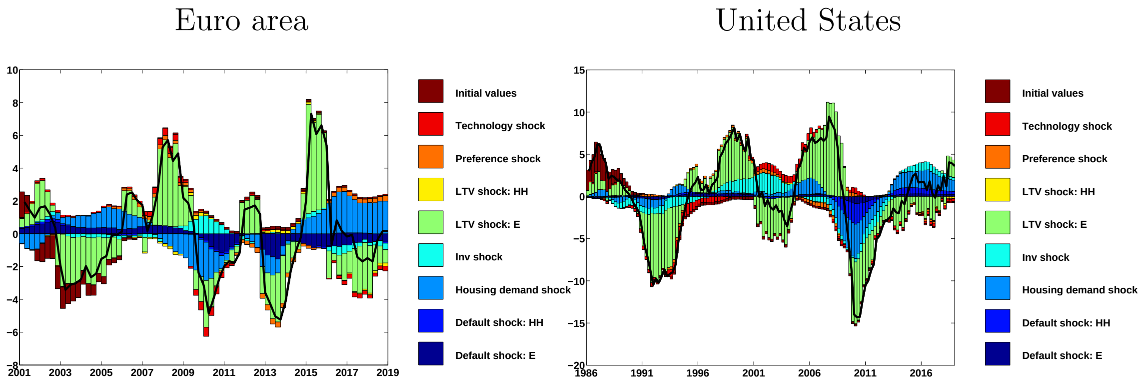
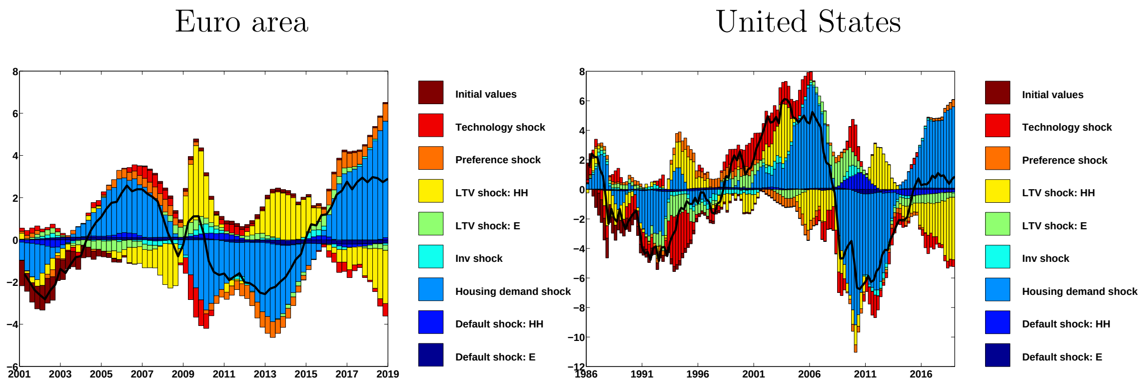


Figure C.12 Loans H



Notes: The solid lines plot actual data. The bars show the contributions of the estimated financial shocks. Data are expressed in terms of percentage deviation from their mean.

Figure C.13 House Prices

Euro area United States

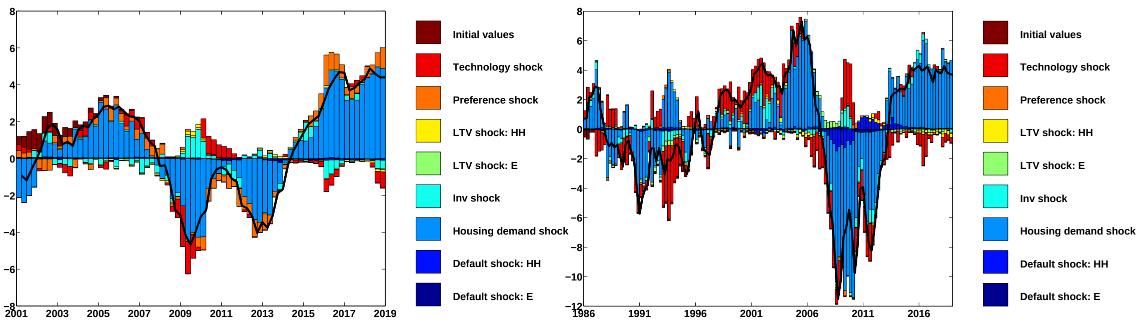
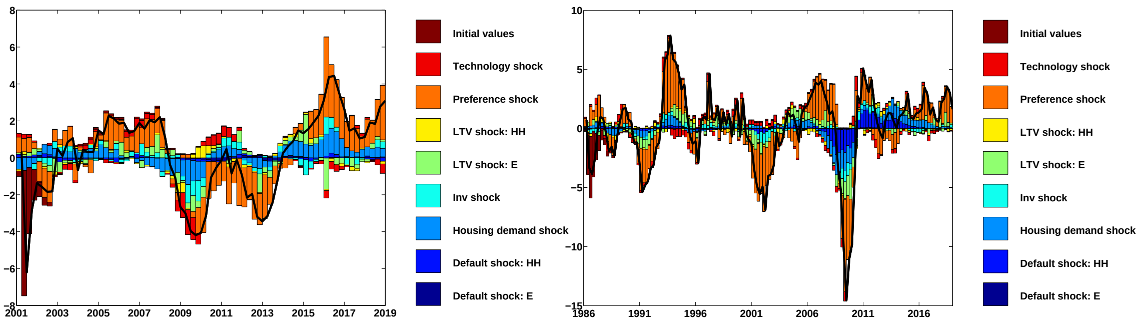


Figure C.14 Employment

Euro area United States



Notes: The solid lines plot actual data. The bars show the contributions of the estimated financial shocks. Data are expressed in terms of percentage deviation from their mean.

D Sensitivity analysis

D.1 Results for the EA model with NPL augmentation

Table D.1 Euro area

Output	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.0	-0.2	-0.4	-0.1	-0.0	0.1	-0.2	0.1	-0.0	0.1	0.0	-0.0	-0.6	0.2
Housing Demand shock	-0.4	-0.7	-1.0	-0.1	0.5	-0.2	-0.0	0.7	0.8	1.1	0.3	0.4	-2.2	3.5
LTV shocks	0.3	0.3	-0.1	0.0	-0.0	-0.0	-0.4	0.2	0.9	-0.6	-0.5	-0.1	0.6	-0.5
Preference shock	1.0	0.3	-0.0	-1.3	-1.4	-1.6	-1.1	-0.1	1.0	2.4	1.1	1.6	0.0	1.8
TFP & Inv. shocks	1.2	-0.5	-4.3	1.7	1.4	-0.4	-0.0	-0.3	-0.8	-0.4	0.1	-0.6	-2.0	-1.1
All shocks (data)	2.3	-0.8	-5.8	0.3	0.5	-2.2	-1.6	0.8	1.7	2.6	1.1	1.1	-4.0	4.1
Investment	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.1	-0.7	-1.0	0.5	0.1	0.5	-0.1	0.5	0.0	0.7	0.1	-0.1	-1.3	1.7
Housing Demand shock	-0.9	-1.9	-2.7	-0.7	1.1	-0.4	-0.1	1.8	2.1	2.9	1.2	1.0	-6.2	9.7
LTV shocks	1.4	1.7	-0.6	0.3	-0.2	-0.1	-1.8	0.7	3.7	-2.3	-2.0	-0.7	2.9	-2.8
Preference shock	1.2	0.1	-0.1	-1.5	-1.8	-1.9	-1.0	-0.0	1.4	2.8	1.1	2.3	-0.4	2.9
TFP & Inv. shocks	4.5	-0.7	-13.1	2.3	4.9	-1.5	-0.1	-1.2	-4.4	1.8	-0.3	-0.9	-7.0	-1.7
All shocks (data)	6.4	-1.4	-17.3	0.9	4.1	-3.4	-3.1	1.7	2.9	5.9	0.1	1.5	-11.4	9.7
Consumption	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	0.1	-0.0	-0.2	-0.3	-0.0	-0.0	-0.2	0.0	-0.1	-0.0	0.0	-0.0	-0.4	-0.4
Housing Demand shock	-0.2	-0.3	-0.4	0.1	0.3	-0.2	0.0	0.4	0.3	0.5	0.0	0.1	-0.9	1.4
LTV shocks	-0.1	-0.2	0.0	-0.0	0.0	0.0	0.1	0.1	-0.1	-0.1	0.1	0.1	-0.2	0.2
Preference shock	1.0	0.4	0.0	-1.2	-1.2	-1.6	-1.1	-0.1	0.8	2.2	1.1	1.3	0.2	1.5
TFP & Inv. shocks	0.1	-0.5	-1.2	1.4	0.2	-0.0	0.0	0.0	0.4	-1.1	0.2	-0.5	-0.2	-0.8
All shocks (data)	0.9	-0.6	-1.8	0.0	-0.7	-1.8	-1.1	0.4	1.3	1.5	1.4	1.0	-1.4	2.1

D.2 Utilisation-unadjusted TFP with augmented measurement equation

No utilisation-adjusted TFP series is available for the euro area. Therefore, we adjust the TFP measurement equation for capital utilisation as follows:

$$data\_tfp = a_t + \alpha \cdot \mu \cdot Z_{KE,t} + \alpha \cdot (1 - \mu) \cdot Z_{KH,t} \tag{D.1}$$

To test the validity of our approach, we run a counterfactual analysis with TFP series unadjusted for utilisation and with the modified measurement equation D.1 for the United States. The outcome, as shown in Figure D.1 and Table D.2, can be compared to the US benchmark model, which uses utilisation adjusted TFP series as observable.

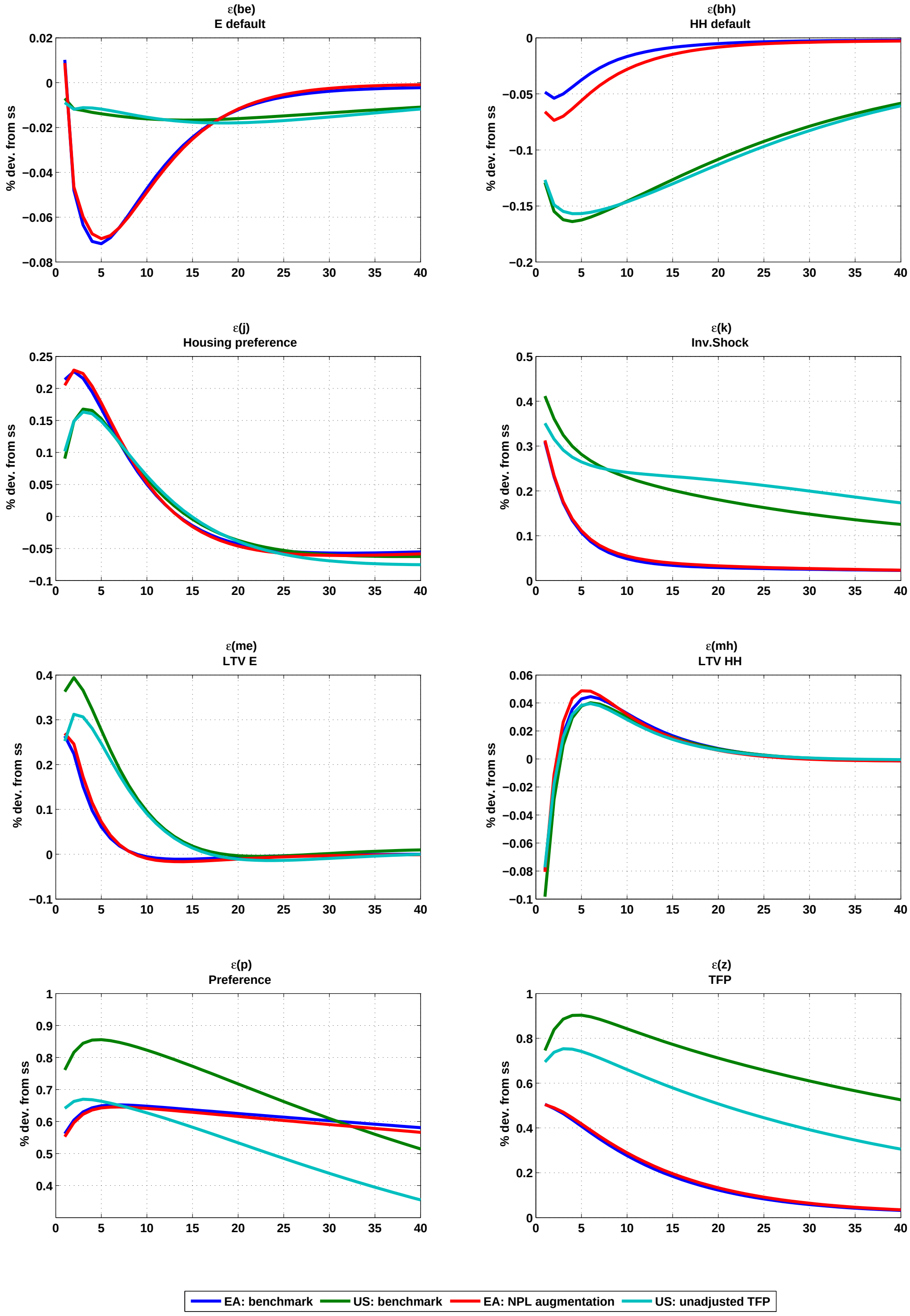
Using this modification, we observe stronger contributions from TFP shocks to the Great Recession in the United States. Nevertheless, financial shocks continue to account for the bulk of the downturn and the subsequent recovery, albeit to a somewhat smaller degree than in the benchmark model. We conclude that this modification allows for a reasonable approximation of the roles played by both TFP and financial shocks. Indeed, given that no utilisation-adjusted TFP series for the EA is available, it remains the only viable approach.

Table D.2 Historical decomposition of real GDP: United States

Output	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.2	-1.4	-1.6	-0.2	0.9	0.6	0.7	0.5	0.3	0.2	0.1	0.1	-3.4	3.3
Housing Demand shock	-0.7	-1.2	-0.9	-0.7	0.0	0.5	1.1	0.9	0.7	0.6	0.2	0.0	-3.4	4.0
LTV shocks	0.9	0.4	-1.0	-0.9	-0.2	0.3	-0.2	-0.1	-0.0	-0.2	-0.0	0.2	-0.6	-0.2
Preference shock	2.0	1.9	-1.5	-1.5	0.4	-1.3	-1.2	0.1	0.4	1.7	1.0	1.6	0.9	2.6
TFP & Inv. shocks	-1.6	-2.5	-2.6	3.0	-0.1	1.0	-0.7	0.2	-0.4	-2.2	-0.3	-0.1	-3.7	-2.6
All shocks (data)	0.5	-2.8	-7.6	-0.2	1.0	1.0	-0.3	1.7	1.0	0.1	0.9	1.8	-10.0	7.1
Contribution to Investment	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.5	-2.7	-2.6	0.5	2.1	1.1	1.4	0.9	0.4	0.2	-0.0	-0.0	-5.5	6.0
Housing Demand shock	-0.6	-1.4	-1.7	-1.5	-0.2	0.4	1.3	1.8	1.2	1.0	0.6	-0.0	-5.2	6.2
LTV shocks	2.8	1.4	-3.1	-3.1	-1.5	1.0	-0.3	-0.4	0.0	-0.7	0.0	0.9	-2.0	-0.9
Preference shock	1.7	1.2	-2.1	-0.6	0.6	-1.4	-1.0	0.5	0.4	1.5	0.7	1.4	0.2	2.7
TFP & Inv. shocks	-0.6	-1.6	-9.8	5.5	3.8	4.6	-0.8	0.9	-3.3	-4.5	0.0	1.0	-6.6	1.7
All shocks (data)	2.8	-3.2	-19.4	0.8	4.8	5.7	0.7	3.7	-1.3	-2.4	1.3	3.3	-19.0	15.8
Contribution to Consumption	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2007-2010	2011-2018
Default shocks	-0.1	-0.9	-1.2	-0.4	0.5	0.4	0.5	0.4	0.2	0.2	0.1	0.1	-2.7	2.3
Housing Demand shock	-0.7	-1.1	-0.6	-0.4	0.1	0.5	1.0	0.6	0.5	0.4	0.0	0.0	-2.8	3.2
LTV shocks	0.3	0.0	-0.3	-0.1	0.2	0.0	-0.1	-0.0	-0.0	-0.1	-0.0	0.0	-0.2	0.0
Preference shock	2.1	2.2	-1.3	-1.8	0.3	-1.3	-1.3	-0.1	0.5	1.8	1.1	1.6	1.2	2.6
TFP & Inv. shocks	-1.9	-2.9	-0.2	2.2	-1.4	-0.3	-0.7	-0.0	0.6	-1.4	-0.4	-0.5	-2.7	-4.1
All shocks (data)	-0.3	-2.6	-3.6	-0.5	-0.3	-0.6	-0.6	0.9	1.7	0.9	0.8	1.3	-7.0	4.2

D.3 Comparison between benchmark and alternative results

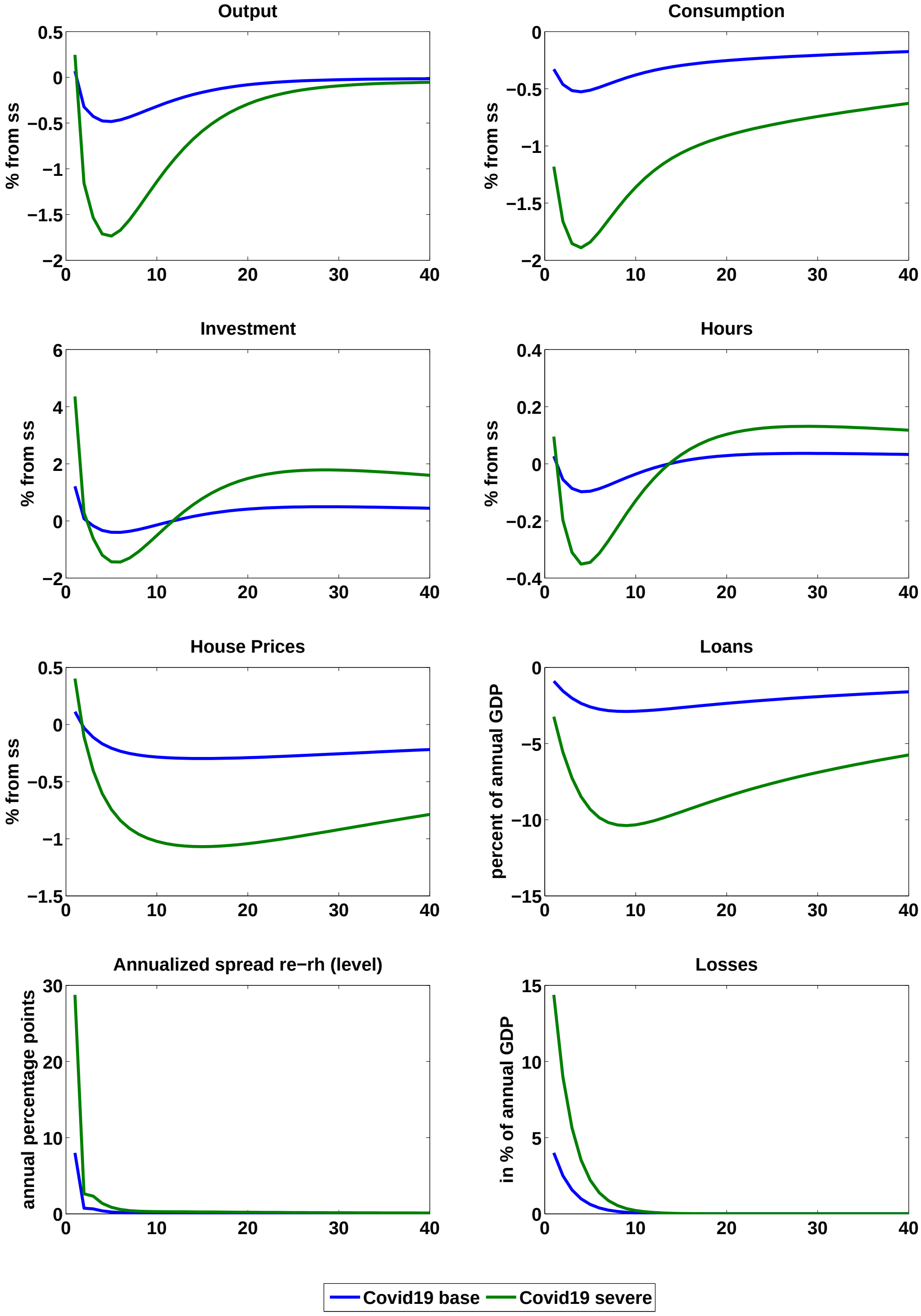
Figure D.1 Reaction of output in response to a one standard deviation shock



Notes: The EA and US results for the benchmark model are described in the main text. For the other EA results, *"NPL augmentation"* illustrates sensitivity with respect to bank loan losses, while for the other US results, *"unadjusted TFP"* illustrates sensitivity with respect to using the utilisation-unadjusted TFP series. All responses are expressed in terms of percentage deviations from steady state.

E Financial amplification due to the COVID-19 pandemic

Figure E.1 Effects of COVID-19-induced increase in entrepreneur loan defaults



Notes: The shocks have been calibrated based on the scenarios presented in ECB, FSR, 2020 May. All responses are expressed in terms of percentage deviations.

Acknowledgements

We would like to thank Matteo Iacoviello for providing useful insights and comments. We also benefited from discussions and suggestions by Matthieu Darracq Pariès, Wouter den Haan, José Maria and Diego Rodriguez Palenzuela, as well as participants at ECB and Eurosystem seminars. All remaining errors are our own. The views expressed in this paper are solely those of the authors and do not necessarily represent the views of the ECB.

Dominik Hirschbühl
European Central Bank, Frankfurt am Main, Germany; email: dominik.hirschbuhl@ecb.europa.eu

Georgi Krustev
European Central Bank, Frankfurt am Main, Germany; email: georgi.krustev@ecb.europa.eu

Grigor Stoevsky
European Central Bank, Frankfurt am Main, Germany; email: grigor.stoevsky@ecb.europa.eu

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-4392-5 ISSN 1725-2806 doi:10.2866/95665 QB-AR-20-127-EN-N